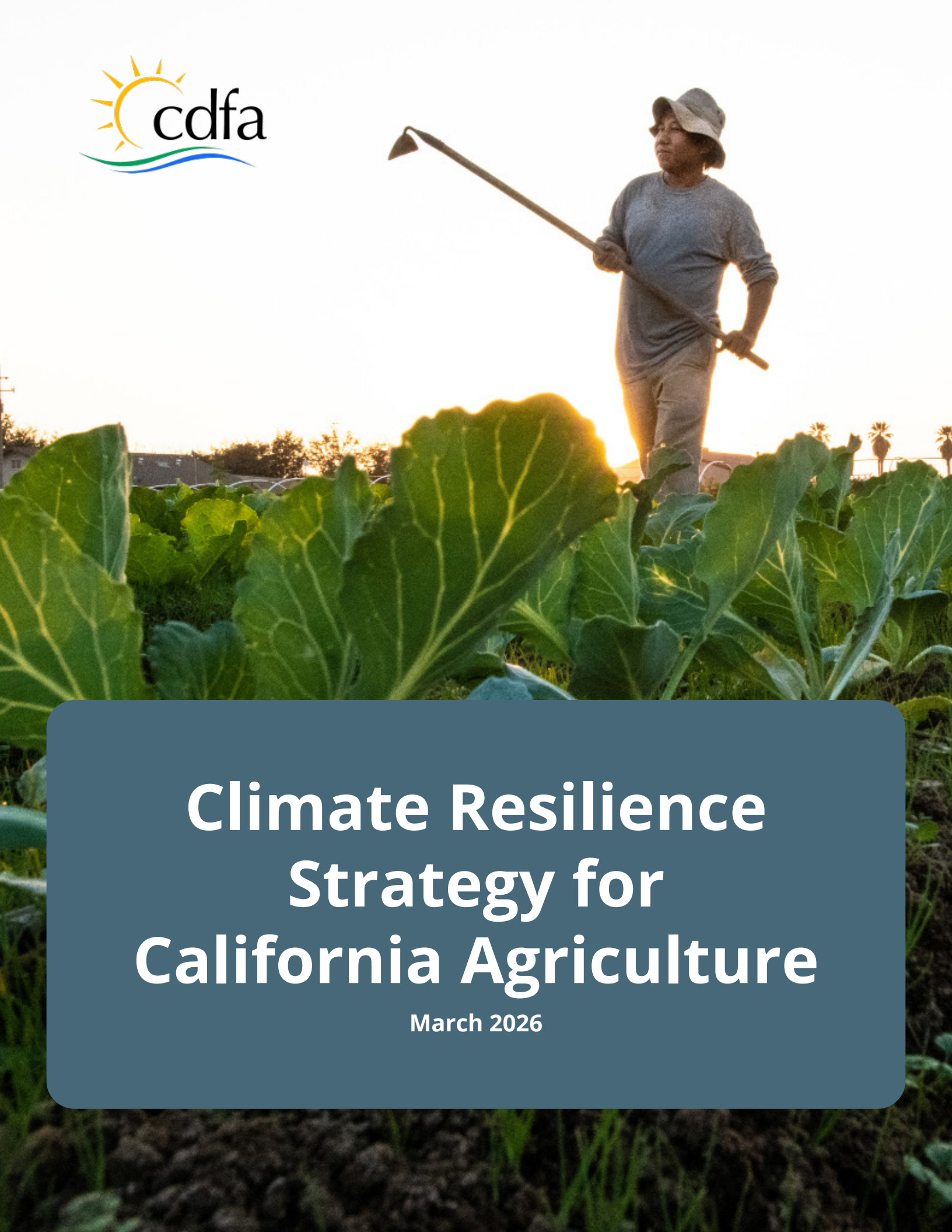

Climate Resilience Strategy for California Agriculture

March 2026

Foreword from the Secretary

Karen Ross

It is with both deep respect for California's agricultural heritage and a profound sense of urgency that I present the Climate Resilience Strategy for California Agriculture. This Strategy represents a pivotal step in defining a shared path forward—one that strengthens our agricultural communities, safeguards our natural systems, and provides leadership to protect the continued vitality of a sector that sustains the health and wellbeing of our state, nation, and world.

Since the establishment of our state, agriculture has been a cornerstone of California's economy, culture, and identity. Today, with a farm gate value of over $60 billion, our state's farmers and ranchers produce more than 400 commodities and provide a significant portion of the nation's fruits, nuts, vegetables, and dairy. And yet, today's farmers, ranchers, and farmworkers navigate a landscape transformed by deep uncertainty: increasingly volatile climate conditions, economic pressures, labor challenges, and evolving regulatory requirements—which cumulatively demand resilience, innovation, and in some cases, adaptation.

Climate change is already altering every dimension of agricultural production. Rising temperatures and shifting precipitation patterns are affecting water availability and irrigation demands, while increased pest and disease pressures threaten yields and farm profitability. These impacts are compounded by extreme weather events—heat waves, wildfires, and storms—that stress not only crops and livestock, but also the people who produce our food. Agriculture is not only responding to these challenges through innovative solutions like on-farm aquifer recharge and grazing for wildfire fuel reduction but is actively mitigating climate change through solutions like carbon-sequestering healthy soils practices, manure management, and reusing biomass as part of the circular bioeconomy.

At the same time, economic realities weigh heavily on farm businesses. Rising input costs, labor shortages, slim profit margins, and fluctuating market conditions make long-term planning difficult for farmers of all scales. Water scarcity and regulatory changes continue to shape decisions on land use and crop selection, even as emerging scientific and technical innovations offer new opportunities for sustainable production and climate adaptation.

Central to this Strategy is the recognition that in agriculture, resilience must be holistic—supporting economic viability, protecting natural resources, advancing equity and workforce wellbeing, and promoting innovative, climate-smart practices. The document is organized around three core pillars that capture this comprehensive vision:

- Support a Thriving and Resilient Food Sector,
- Protect Natural Systems Critical to Agriculture, and
- Encourage Resilient Agricultural Practices.

The Strategy reflects the invaluable perspectives and expertise of California's diverse agricultural community. It was shaped through extensive engagement with farmers and ranchers, technical experts, community organizations, and public agency partners. The Strategy not only catalogues the challenges before us, but also identifies strengths, ongoing actions, and new strategies that can build resilience across the agricultural landscape.

The Strategy calls on us to strengthen our collective commitment to agriculture that is resilient, equitable, and adaptive to the realities of a changing climate. Together, we can ensure that California agriculture remains a model of innovation and stewardship for generations to come.

Yours Truly,

Karen Ross

Secretary, California Department of Food and Agriculture

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We acknowledge and thank the following authors and contributors to this Strategy. We would also like to thank California Department of Food and Agriculture Secretary Karen Ross for her support and leadership throughout its development.

CDFA would also especially like to acknowledge, in memoriam, the contributions of Vicky Dawley, member of the Environmental Farming Act Science Advisory Panel from 2017-2025. Vicky was an articulate and strong advocate for the need for accessible and dependable technical assistance to support farmers and ranchers in adapting and building resilience to climate change.

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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.

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.

Table 1: Ag Vision 2030

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: Key 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 that categorize actions into expected outcomes of these actions. 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.

Key Objectives

Support a Thriving and Resilient Food Sector

1. Foster a Robust and Sustainable Agricultural Economy
2. Ensure a Water System for Food System Resilience in a Hotter, Drier Future
3. Support Agricultural Workforce Wellbeing and Health
4. Protect Animal Health
5. Advance Energy Efficiency and Decarbonization for Agricultural Operations

Protect Natural Systems Critical to Agriculture

6. Conserve Productive Farmland
7. Deploy Sustainable, Adaptable, and Integrated Pest Management
8. Boost Biodiversity on Farm Lands

Encourage Resilient Agriculture Practices

9. Enhance Agricultural Practices to Support Clean Air Communities
10. Advance Climate-Smart and Healthy Soils Practices
11. Improve Ranching Sustainability and Rangeland Management
12. Increase Dairy Farming Sustainability

Goals

1. Improve the Bottom Line for Farmers

Actions that positively impact the livelihoods of individual farmers and ranchers.

2. Reduce Greenhouse Gas Emissions

Actions that reduce greenhouse gas emissions and/or sequester carbon to help the state reach its carbon neutrality goal by no later than 2045.

3. Support Economic Development

Actions that use interdisciplinary problem solving to bolster economic growth and facilitate new opportunities for the agricultural sector.

4. Provide Health and Environmental Benefits

Actions focused on improving the health and wellbeing of people, animals, and the environment.

Equity Principles

Health & Wellbeing | Accessibility | Capacity Building | Accountability & Transparency | Cultural Relevance | Financial Viability

Figure 1: RSA Framework

Plan Organization

The RSA, is organized by three pillars, as outlined above in Figure 1. 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: Shares relevant case studies in sidebars.
4. Implementation Table: At the end of each chapter, an implementation table with actions and lead implementer is included.

Overarching Goals:

While the individual actions in the RSA are organized by chapter, they are also categorized by goals—broad, overarching outcomes that are expected as a result of each action. While only one goal is assigned per action, many of these actions drive multiple beneficial outcomes for climate resilience. The overarching goals recognized in this strategy include:

Goal 1: Improve the Bottom Line for Farmers

Goal 2: Reduce Greenhouse Gas Emissions

Goal 3: Support Economic Development

Goal 4: Provide Health and Environmental Benefits

Figure 2: RSA Creation Timeline

Engagement Process

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 Scientific Advisory Panel on Resilient and Sustainable Agriculture, or SAP (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 to create a working draft. The working draft was circulated for review by state agencies in Summer 2025 and edits were incorporated before releasing the working draft for public review from October–November 2025 and was finalized in early March 2026.

Serving the Diversity of California Farms and Farmers

There are more than 400 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 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]

Tribal Stewardship

Since time immemorial, California Native American tribes have been stewards of California lands. Tribes have continued to care for the land despite centuries of violent land theft and exclusions. Tribal land stewardship includes Traditional Ecological Knowledge (TEK), or the knowledge of ecological relationships, resource management, and sustainability that is passed down through generations via oral histories, ceremonies, and lived experiences. TEK integrates observation with values, ethics, and community responsibilities, offering holistic perspectives that are vital to environmental stewardship and resilience. TEK does not follow a one-size-fits-all model; rather, it is site- and place-specific and is defined differently by different communities.[4] TEK 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 tribes, acorn remains connected to cultural identity.[5]

Today's California Native American tribes and the State of California are working 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.[6] AB 923 (Ramos, 2022) encouraged the State of California and its agencies to consult on a government-to-government basis with federally recognized and, as specified, with non-federally recognized tribes to allow meaningful participation by tribal officials in the development of policies and programs that have tribal implications. The California Natural Resources Agency (CNRA) lists guidance for tribal consultation to ensure consistent consultations within their agency—this document can also serve as a guide for other state agencies to improve consultations with tribal entities. CNRA has recently released a draft Tribal Stewardship Policy and Toolkit that will provide policy and resources to institutionalize durable tribal-state partnerships and to advance durable tribal access, collaboration, and ancestral land return across California. The Policy and toolkit sets the goal of expanding tribal stewardship of the land and coastal waters to at least 7.5 million acres through access, ancestral land returns, and collaborative agreements for the stewardship of specific areas, species, and natural resources.

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.

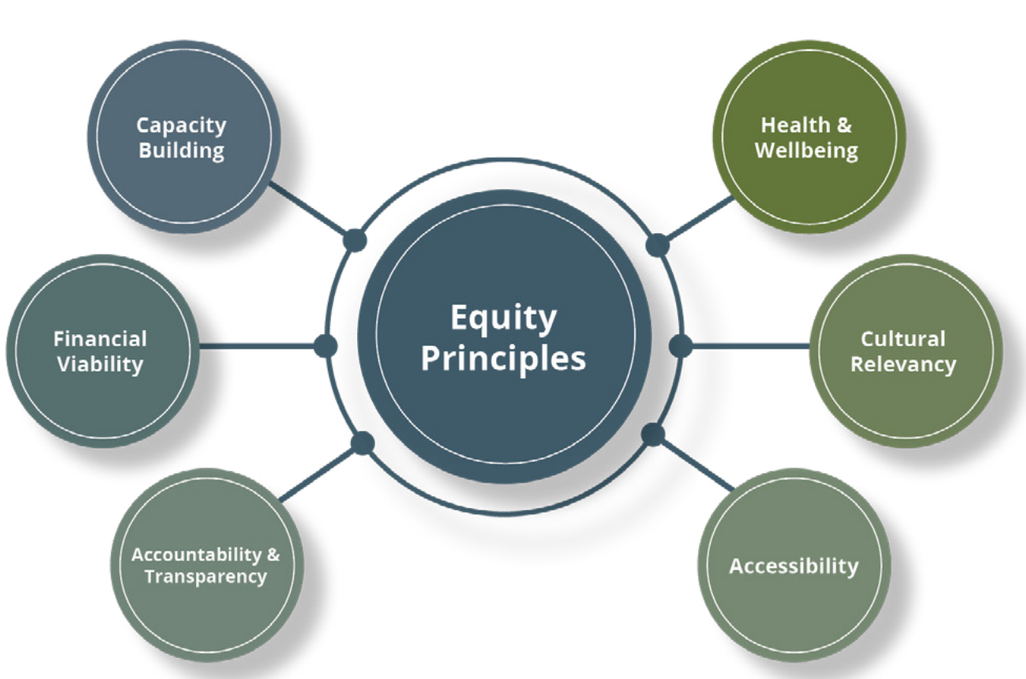


Figure 3: Equity Principles and their Objectives

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.[7] 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 crops are grown nowhere else in the continental U.S., including almonds, walnuts, pistachios, prunes, grapes and raisins, olives, kiwis, figs, nectarines, and pomegranates. California is also the largest dairy state in the nation, producing an estimated 20 percent of the nation's fluid milk in addition to other dairy products. 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.[8]

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.[9]

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.[10]

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 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.[11] 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.[12] 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.[13]

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.[14] In the northeast corner of the state, the Modoc Plateau produces potatoes, alfalfa, hay, and grains such as barley and wheat.[15]

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 enforces some of the strictest environmental and pesticide safety standards in the country while also upholding food safety standards and championing climate-smart agricultural efforts.[16]

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). Programs like the Fertilizer Research and Education Program provide outreach and research on best management practices and tools to help reduce water and chemical use while improving yields and protecting ecosystems. Grant programs like CDFA's Healthy Soils, State Water Efficiency and Enhancement, and Alternative Manure Management Programs provide financial support to farmers implementing climate-smart practices, like planting cover crops, installing efficient irrigation systems, or helping manage dairy and livestock manure for methane emission mitigation.

Efforts to protect biodiversity, improve soil health, and support pollinator populations are also front and center through programs like the Apiary Protection Program, Border Protection Stations, and Pollinator Habitat Program. 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 modernizing 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.[17] 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.[18] 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.[19]
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.[20]
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.

Table 2: Defining Key Terms

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 risk of flooding and saltwater intrusion risk 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.[21] 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.[22]
- Diminishing meat and milk production as animals experience extreme heat events causing impacts ranging from discomfort to mortality.

- Pest and disease pressure increase with climate change, further impacting agricultural operations and lowering crop yields.[23] These effects are already present—for example, the life cycle of navel orange worm has sped up due to the warming temperatures.[24]
- 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.[25]
- Reduced surface water and increased evapotranspiration due to higher temperatures 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.[26]
- Increased pumping of groundwater contributes to lower groundwater levels, degradation of water quality, depletion of interconnected surface waters, saltwater intrusion, reduced groundwater storage availability, and subsidence from the compaction of clays.
- Subsidence and depletion of interconnected surface waters have resulted in reductions of surface water deliveries. Subsidence is causing extensive canal damage where increased pumping of groundwater near critical infrastructure is occurring. Depletion of interconnected surface water streams has also impact aquatic habitats.
- Rising sea levels are causing saltwater intrusion that is impacting aquifers beneath low-lying coastal farms. Increased groundwater pumping in coastal aquifers exacerbates saltwater intrusion.

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.

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.

Croplands and rangelands are well suited for implementing climate-smart practices which sequester carbon and reduce GHG emissions. Soil carbon in croplands and rangelands can play a critical role in addressing climate change by acting both as a carbon sink and as a foundation for resilient and productive landscapes.[27] Through photosynthesis, plants use sunlight to draw carbon from the atmosphere and convert it into energy. Plants then can add organic carbon to soil via the addition of organic matter from plant residues, roots, and dead plant matter.[28] Using practices such as cover cropping, reduced tillage can help build and maintain soil carbon, while at the same time, soil carbon can be lost via management practices that induce erosion or decomposition of the organic matter such as intensive tillage and overgrazing.[29]

The second edition of California's Natural and Working Lands Carbon Inventory indicates that the state's natural and working lands have absorbed more carbon than they released since 2001, which helps to counterbalance the emissions from catastrophic forest fires. Cropland and grassland carbon stocks represent about 13 percent of total ecosystem carbon.[30] Therefore, protecting existing soil carbon stocks and enhancing carbon sequestration through climate-smart land management are essential strategies for both climate mitigation and adaptation in agricultural systems.

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

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.

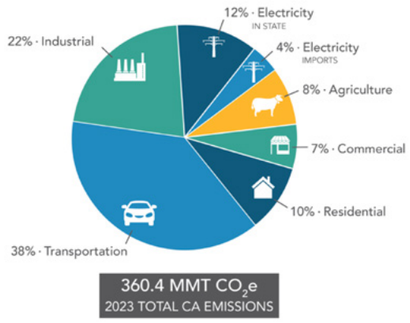


***Figure 4:** [California's 2023 GHG Emissions by Main Economic Sector]*

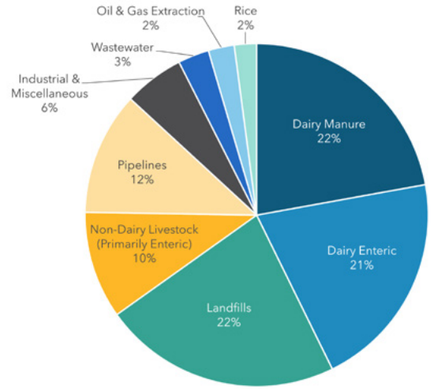


Figure 5: Agriculture Sector Emissions in 2023 (Source: [AB 32 GHG Emissions Inventory 2025 Edition Documents] | California Air Resources Board)

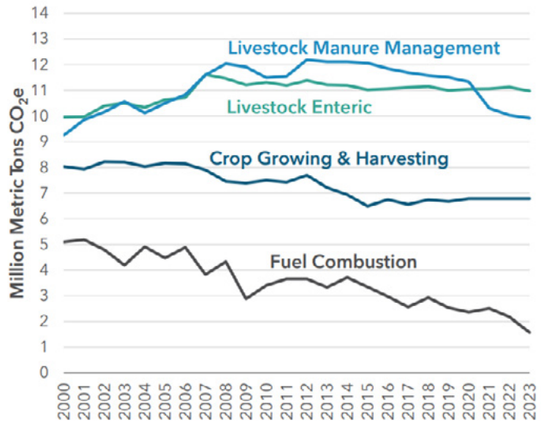


Figure 6: [Agriculture Sector Emissions by Sub-Sector] | California Air Resources Board

This figure presents the trends in emissions from 2000 to 2023 from livestock manure management, livestock enteric fermentation, crop growing and harvesting (fertilizer use, soil preparation and disturbance, and crop residue burning), and fuel combustion (water pumping, heating buildings, processing commodities, and tractors).

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.

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 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, 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.

Regenerative Agriculture

There are many existing definitions for the term "regenerative agriculture." Between 2023 and 2025, CDFA hosted a number of stakeholder meetings, working groups, meetings of its Scientific Advisory Panel and State Board of Food and Agriculture in order to finalize a definition for department use. While not intended to function as a definition for purposes of certification, the definition provides guidance on the term as it applies to the state's own policies and programs. The following definition was adopted by the department on March 1, 2025:

Definition of "Regenerative Agriculture" for State Policies and Programs

"Regenerative agriculture," as defined for consideration by state agencies and departments, is an integrated approach to farming and ranching rooted in principles of soil health, biodiversity and ecosystem resiliency leading to improved targeted outcomes.

Regenerative agriculture is not an endpoint, but a continuous implementation of practices that over time minimize inputs and environmental impacts and further enhances the ecosystem while maintaining or improving productivity, economic contributions and community benefits. "Regenerative agriculture" is an ongoing continuum of sustainability for California's farmers and ranchers, informed by current science as well as the traditions and innovations from the original Indigenous stewards of the land.

Examples of target outcomes include

- Building soil health, soil organic matter and biodiversity; (Healthy Soils Program), (AB 1757)
- Increasing statewide implementation of conservation practices that improve soil health, sequester carbon and reduce greenhouse gases; (USDA NRCS Conservation Practice Standards)
- Furthering sustainable pest and integrated pest management to reduce the reliance on pesticides; (Accelerating Sustainable Pest Management: A Roadmap for California), (UC Statewide Integrated Pest Management), (USDA NRCS Pest Management Conservation System)
- Protecting the welfare and care of animals in agriculture; (Animal Care Program)
- Building healthy, local communities; (Ag Vision)
- Protecting spiritual and cultural traditions as well as supporting Native-led stewardship practices;
- Minimizing negative impacts to other target outcomes;
- Maintaining positive impact on the economic vitality/livelihoods of farmers and ranchers.

Regenerative agriculture will require processes, practices, monitoring, evaluation, and innovation to be customized to specific production systems, ecoregions, and local Indigenous cultural regions. Practice selection is based on the best available science and practice, including but not limited to, organic and traditional ecological knowledge, for production systems.

State agencies and departments are encouraged to coordinate with the Department, contingent upon resources, in the development of measurable and verifiable outcomes related to individual policies and programs and are responsible for incorporating verification and reporting.

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. Progress towards these targets will be reported every two years. The first progress report was released in 2026.
- **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 operational 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, including 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.

Table 3: Summary Table of Ag Emissions, Solutions, State Targets, & Existing Programs

GHG Emissions Sources in Ag+	Solutions	State Targets and Mandates	Resilience Benefits	Programs to Advance Solutions*
Enteric methane (37.5% of ag emissions)	Research and implementation of strategies to reduce enteric methane	SB 1383: requires dairy and livestock methane emission reductions to 40% below 2013 levels by 2030		LEMER-RP, Clim^{3}ate-RP
Manure emissions (33.9% of ag emissions)	Conversion to drier manure management and pasture-based systems to reduce manure methane and increase compost supply Installation of anaerobic digesters to capture methane from manure lagoons Research and verification of current and new practices for manure management	SB 1383: requires dairy and livestock methane emission reductions to 40% below 2013 levels by 2030	Improved air and water quality, diversified income opportunities	AMMP, DDRDP, Dairy Plus , Clim3ate-RP
Crop growing & harvesting (23.2% of ag emissions) Includes: nitrous oxide emissions from fertilizer use & irrigation; soil carbon loss from soil disturbance; carbon dioxide emissions from crop residue burning	Improvement of irrigation efficiency and nutrient management to reduce nitrous oxide emissions	Irrigated Land Regulatory Program & CV SALTS both aim to reduce excess/ inefficient nitrogen/ irrigation application, which are also the driving causes of nitrous oxide emissions.	Reduced costs (fertilizer), protection of water quality, conservation of water and reduced overdraft	SWEEP, WETA, HSP, FREP
	Transition to fewer synthetic inputs, efficient fertility management, and integrated pest management systems to reduce fossil fuel-based fertilizer and pesticide use	AB 1757: 10% organic acreage by 2030, 15% by 2038, 20% by 2045 (also in Scoping Plan); Sustainable Pest Management (SPM) Roadmap: Phaseout of high-risk pesticides by 2050	Resilience against pest pressure	HSP, OTP, AMMP, BIFS, FREP

GHG Emissions Sources in Ag+	Solutions	State Targets and Mandates	Resilience Benefits	Programs to Advance Solutions*
Crop growing & harvesting (23.2% of ag emissions) Includes: nitrous oxide emissions from fertilizer use & irrigation; soil carbon loss from soil disturbance; carbon dioxide emissions from crop residue burning	Adoption of soil health practices to reduce soil carbon losses and sequester carbon	AB 1757: additional 140,000 ac/yr through 2030; additional 190,000 ac/yr through 2038; additional 190,000 ac/yr by 2045	Soil health	HSP, PHP, OTPP
	Adoption of alternatives to agricultural burning (e.g., whole orchard recycling, chipping orchard waste) to reduce carbon dioxide emissions and return carbon to soil	CARB & SJVAPCD: Near-complete phase out of agricultural burning by 2025	Soil health, Air quality	SJVAPCD Ag Burning Alternatives Program, HSP
Fuel combustion (5.4% of ag emissions)	Decarbonization of ag energy use through electrification of irrigation and ag equipment and deployment of on-farm renewable energy	Scoping Plan: Electrify 25% of agricultural energy demand by 2030 and 75% by 2045; Clean Air Act Air Quality Standards	Reduced costs (labor, energy)	FARMER, CORE, FPIP, SWEEP
All of the above	Increase technical assistance capacity to support farmers and ranchers in adopting solutions described above and improve access to climate disaster relief funds	AB 2377 – 5% of budgets for climate smart agricultural programs required to go to technical assistance – HSP, SWEEP	Knowledge sharing and education	CSA-TAP, CUSP, C2P2, TAP, WETA

+Data Provided by CARB from 2025 edition of AB 32 Greenhouse Gas Inventory

*Program Acronyms: AMMP: Alternative Manure Management Program, BIFS: Biologically Integrated Farming Systems Program, Dairy Plus: Dairy Plus Program, DDRDP: Dairy Digester Research & Development Program, C2P2: California Conservation Planning Partnership, Clim3ate-RP: California Livestock Methane Measurement, Mitigation, and Thriving Environments Research Program, CORE: Clean Off-Road Equipment Vouchers, CSA-TAP: Climate Smart Agriculture Technical Assistance Program, CUSP: California Underserved and Small Producer Program, FARMER: Funding Agricultural Replacement Measures for Emission Reductions, FPIP: Food Production Investment Program, FREP: Fertilizer Research and Education Program, HSP: Healthy Soils Program, LEMER-RP: Livestock Enteric Methane Emission Reduction Research Program, OTPP: Organic Transition Pilot Program, PHP: Pollinator Habitat Program, SJVAPCD Ag Burning Alternatives Program: San Joaquin Valley Air Pollution Control District Ag Burn Alternatives Grant Program, SWEEP: State Water Efficiency and Enhancement Program, TAP: Technical Assistance Program (Food Safety Resource for Small and Very Small Produce Farms), WETA: Water Efficiency Technical Assistance

A Path Forward

This Climate Resilience Strategy for California Agriculture outlines many impacts of climate change on 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:

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 clean 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.

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.

California has the largest and most diverse agricultural economy in the United States. In 2024, farmers and ranchers generated over $61.2 billion in sales and produced more than 400 crops, including over a third of the nation's vegetables, nearly three-quarters of its fruits and nuts, and more than 18 percent of its milk. However, farmers and ranchers face mounting economic pressure from climate change, slim profit margins, and volatile markets. Droughts, wildfires, floods, extreme heat, and shifting weather patterns have damaged crops and livestock, increased production costs, forced widespread land fallowing, and intensified pest pressures, with impacts expected to worsen over time. At the same time, farmers and ranchers operate with high input, labor, land, and equipment costs.

This chapter discusses a range of policy, program, and investment solutions to help farms and ranches thrive amid climate change, including measures that reduce climate-driven risk, strengthen financial resilience, support innovation, stabilize markets and supply chains, and build a climate-smart agricultural workforce.

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.[31]

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.[32] 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).[33] For lands that stay in production, pumping and other production costs increase during droughts; the 2021 drought increased pumping costs statewide by $184 million.[34] 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 Chapter 7, Deploy Sustainable, Adaptable, and Integrated Pest Management, for more information). These climate impacts are only expected to worsen into the future.[35]

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.[36]

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.[37] 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 2024, California agriculture was responsible for $23.8 billion worth of agricultural exports.[38] 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.[39]

Strategies and Actions

There are many 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 stability and strengthening measures, and opportunities to build a climate-smart agricultural workforce.

Strategy 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 1: Improve the Bottom Line for Farmers

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, and that the national food supply is protected.

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.[40] 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.[41] On-farm action is needed to help build resilience against the impacts of climate change to mitigate the need for such pay outs.

Stakeholder Feedback

Stakeholders want to see insurance expand to cover not only production losses but also climate or disaster-related marketing losses, suggesting federal models such as Small Business Administration's Economic Injury Disaster Loan and Paycheck Protection Program and California's Quarantine Insurance Program.

Stakeholders support expanding insurance options for specialty crop growers, especially tree and other perennial crops, and encourage the expansion of insurance to better serve small-scale growers and extend insurance payouts to farmworkers also affected by crop losses.

Stakeholders also suggested including the implementation of climate-smart agricultural practices as one way to receive lower lending rates as an act of on-farm risk reduction.

Most farms in California are small farms.[42] 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.[43] 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.[44] This may be because of lasting effects of historical racial discrimination against minority groups.[45] 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 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.[46]

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, instead of 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

Stakeholder Feedback

Stakeholders would like to see creditors and insurers work together to help enable rapid payment assistance in times of need. Suggestions include the creation of a disaster line of credit to couple with parametric insurance to minimize damages and losses.

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.[47] 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 1: Improve the Bottom Line for Farmers

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 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.

Case Study: Supporting Communities through Providing Farmers with Direct Relief

Funding Program: California Underserved and Small Producers Program

Years Project Active: August 2023 to August 2024

Project Implementation Counties: Riverside, San Bernardino

CDFA's **California Underserved and Small Producers Program** (CUSP) helps support small- and medium-scale California agricultural producers and socially disadvantaged farmers and ranchers through direct relief grants coordinated through regional partners. In the Inland Empire and Coachella Valley regions, droughts, extreme heat waves, flooding, and increased wind events are becoming more common, affecting farmers through weather-related crop failure, increased labor costs, market disruptions due to delays in the harvest season that can shift a farmer out of the peak market window, and challenges with finding nursery stock for replanting; all of these impacts hit small- and medium-scale producers especially hard.

Susie Kirschner (center) and the Inland Empire Resource Conservation District Sustainable Agriculture Team.

The Inland Empire Resource Conservation District (IERCD) has been working to promote good stewardship of our soil, water and other natural resources in their region by coordinating cooperation between landowners, local, state and federal agencies, the agricultural community, and environmental and community groups. IERCD was awarded a CUSP block grant in 2023 and have provided 75 grants thus far to farmers to reimburse costs from crop loss due to water stress or fallowed fields, increased electricity use from increased pumping, and additional equipment expenses and upgrades. Susie Kirschner is IERCD's Conservation Program Manager overseeing their agriculture and forestry work, including coordinating management of the CUSP grant. For Kirschner, climate resilience is all about the "ability to adapt, respond, and recover to the changes we are experiencing from climate change". She recognizes that this isn't an easy goal to achieve, but "with technical support and funding, farmers can be both better prepared to face these climate change impacts and have the resources necessary to recover."

*"**Relief grants** available through the CUSP program are a **lifeline** for producers experiencing significant loss and allow them to continue growing for another season and make the necessary upgrades to be **responsive to future climate** impacts. As local service providers, we have delivered relief checks to farmers in tears because of what this funding means for their farm business and family. It's **not just bringing relief** to their farm operation to cover expenses, but also to the individual farmer who is experiencing **extreme personal hardship** from the financial impacts climate change is having on their livelihood. This brings **great meaning** to our work at the IERCD and we are **grateful** to CDFA for the opportunity to bring this **life changing relief** funding to farmers."*

– Susie Kirschner

Congresswoman Nora Torres' field representative presents the Inland Empire Resource Conservation District and Don Gaspar, an Inland Empire farmer, with awards at IERCD's 2023 Annual Farmer Appreciation Event.

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 1: Improve the Bottom Line for Farmers

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 around food safety, environmental impacts, worker treatment, and more 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 workload associated with meeting or exceeding these regulatory goals. 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.[48]

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:

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.[49]
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.

In 2025, CDFA, CalEPA, and the State Water Resources Control Board concluded a regulatory alignment study to 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, the California Water 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, support technical assistance providers, such as agricultural ombudsmen, who to provide guidance on regulatory compliance to producers, and seek to streamline existing regulations and remove outdated ones.[50]

Stakeholder Feedback

Regarding regulatory streamlining efforts, stakeholders support these efforts, but emphasized the importance of considering all farm types and sizes, for example, small and diversified farms as well as large single-crop farms. They also reiterated the importance of clear data use policies and adherence to data privacy laws.

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 and development of agtech to optimize inputs and improve efficiency.

Goal 1: Improve the Bottom Line for Farmers

Agriculture faces growing challenges from rising input costs and the increasing impacts of climate change. However, advancements in agriculture technology (agtech)—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.

Stakeholder Feedback

Stakeholders would like to see agricultural technology development that addresses real-world systems and operational challenges while protecting the environment, climate, and health. They recommend early and ongoing collaboration between technology companies and farmers to ensure new technology is accessible to all producers, regardless of scale.

The most significant cost-saving benefit of agriculture technology 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, nutrient management technology, aided by soil sensors and machine learning algorithms, ensures fertilizers are applied in optimal quantities, preventing excess use and reducing expenses on inputs. One study found that nitrous oxide emissions from California croplands were likely reduced by just over 7 percent from 2001 to 2010 through the implementation of more precise irrigation systems such as drip and subsurface drip systems—improving water use efficiency and reducing greenhouse gas emissions.[51]

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, agriculture technology 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 agtech 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: Improve the Bottom Line for Farmers

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 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 outreach and 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 2026), 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 outreach and 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 3: Support Economic Development

Strong internet connectivity is key to rural community economic development, improved healthcare, education, and public safety.[52] 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 benefit from a variety of technologies.[53]

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

Goal 3: Support Economic Development

A changing climate may provide opportunities to increase production of crops not traditionally grown in California's higher latitudes, such as avocados, mangos, and agave. Additionally, university researchers, private industry, and growers 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.

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 3: Support Economic Development

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

Stakeholder Feedback

Stakeholders would like to see more collaboration across state agencies to work on state procurement of food produced using climate-smart practices, especially uplifting any new procurement projects coming online through the 2024 Climate Bond.

Case Study: Strong Food Systems Support Community Resilience

Project Funding Program: Resilient Food Systems Infrastructure

Awarded Organization: Raul & Family Farms

Award Year: 2024

Project Implementation County: Riverside

The Raul and Family Farms team

A field of springtime leafy greens

Climate change is shortening and shifting the harvest window for some crops, leading growers and their teams to work around the clock and through extreme weather events to meet their harvest goals. As these extreme weather events become more frequent, growers must adapt rapidly. CDFA's **Resilient Food Systems Infrastructure** (RFSI) program funds projects aiming to maintain and improve food and agricultural supply chain resiliency. Regional food hubs can buffer the pressure these growers are facing from climate change, as they are critical community centers that promote local economies by serving as focal points between farmers and consumers.

Riverside County has **moderate levels of food insecurity**; differences in these rates by race and ethnicity underline the need for growers to understand the needs of the communities they serve. For almost 30 years, Raul & Family Farms have been serving their local and regional communities by cultivating and harvesting various produce ranging from tomatoes and strawberries to leafy greens and sugar snow peas. Mariela Buenrostro oversees the operations of sales, food safety, and communications for the Farms. With RFSI funding, Raul & Family Farms have been able to invest in infrastructure that was previously unaffordable. Mariela notes that "[h]aving refrigeration big enough for our farm will open many doors—for possible value-added goods, for collaboration with other farmers, and eventually a food-hub for our city."

With proper refrigeration, produce can have a longer shelf life to ultimately bring down operational costs and increase labor flexibility. This equipment upgrade allows them to meet their mission "to expand the bounty of a sustainably grown, farm fresh harvest in raw & value-added forms … We strive to have a farming business that is completely self-sufficient [by] harvesting, storing, processing and selling our own produce."

*"Farmers like us are disappearing because **our work is not easy**…. I am **extremely proud of my roots**, we all are. Our **culture** is very present in everything we do."*

– Mariela Buenrostro, Raul & Family Farms

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 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 1: Improve the Bottom Line for Farmers

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 compost to 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 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 further investment 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—one 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. One example of this is CalRecycle's work to divert 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.

1.4.3 Ensure the highest and best use of diverted organics to animal feed while ensuring safety.

Goal 3: Support Economic Development

Another way in which the agricultural community has been helping to divert waste from landfills is through livestock feed. Over 85 percent of what cattle consume is feeds that humans cannot utilize, including by-products (40 percent) and forages (45 percent).[54] If these by-products were not diverted to feed, they would likely go to landfill.[55] The carbon emissions of sending by-products to a landfill are, on average, 60 percent greater than feeding them to cows.[56] Livestock "upcycle" by converting forages and by-products into high quality, nutritious product such as meat, milk, and eggs.

Over 12 million tons of human food waste is currently being diverted to animal feed within California's livestock feed industry.[57] The California feed industry has been sustainably up-cycling for generations by diverting locally produced food waste to nutritious animal feed. This reduces the need for production or import of traditional feedstuffs for California livestock and provides an affordable alternative to traditional feedstuffs which is crucial for the success of California ranching and farming families. The availability of food waste diversion to animal feed is especially critical amid drought and supply chain volatility.[58]

To incentive this diversion of human food waste from landfills, CDFA implemented a reduced inspection tonnage tax for eligible human food by-products diverted to livestock feed without additional manufacturing/processing. Additionally, firms solely dealing in the diversion of eligible human food by-products to livestock feed may be eligible for a reduced commercial feed license fee.

Stakeholder Feedback

Stakeholders note significant opportunity related to SB 1383 compliance, diversion of organic materials, and the circular economy. Many commenters pointed to the potential for composting of organic materials including manure to improve soil on farms, and recommended that the state create regional incentives to coordinate urban organic waste with rural demand. (See Chapter 10 on Healthy Soils for additional actions and recommendations related to compost.)

CDFA's Commercial Feed Regulatory Program (CFRP) and Safe Animal Feed Education (SAFE) Program will maintain their role as a resource to industry; providing education, guidance and regulatory oversight to ensure diversion of organic waste to animal feed and use of innovative animal feed products provides for a safe, clean, and wholesome supply of meat, milk, and eggs for the benefit of the consumer in California and nationwide. CDFA's CFRP will continue their reduced commercial feed license fee and reduced inspection tonnage tax for the diversion of eligible organic waste that is safe and suitable for use as animal feed. The CFRP and SAFE will also play a role in communicating the importance of California's animal agriculture industry in utilizing the highest and best use of organic waste products which may not be suitable for human consumption, but are safe and suitable for animal feed.

Synthetic Fertilizer and the Future

The synthetic production of nitrogen fertilizers through the Haber-Bosch process combines hydrogen and nitrogen to produce ammonia. Currently, much of the hydrogen is sourced from fossil-fuel derived natural gas, which is a major source of global GHG emissions.

Fortunately, alternatives are on the horizon. The hydrogen used to make ammonia can be produced in ways that do not rely on fossil fuels, like using renewable energy to power electrolysis or converting waste into biogenic hydrogen. There are also opportunities to capture carbon emissions that result from conventional reformation of methane into hydrogen. For California, producing fertilizer in-state, utilizing the agricultural bioeconomy to produce hydrogen could help decrease transportation and distribution costs for fertilizer.

Building California's Bioeconomy

State agencies, non-profits, scientific, and for-profit organizations are working to intentionally design a circular bioeconomy in the agricultural sector 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 reuse of materials 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 chapter 3, Support Agricultural Workforce Wellbeing and Health, and Tools sections.) 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.

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.[59]

1.5 Increasing investment in climate-smart agriculture.

Challenges with Existing Markets

Since 2014, CDFA has invested more than $800 million in on-farm climate-smart agricultural practice implementation through the Office of Agricultural Resilience and Sustainability. In addition, a multitude of other state agency-led actions have dedicated time and resources to helping achieve our state's ambitious climate goals. However, scaling up climate-smart agricultural practices will require ensuring that those practices are accounted for and valued by supply chains on an ongoing basis.

One of the existing options for driving investment is through voluntary carbon markets (VCMs). 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 CO_2 or other greenhouse gas emissions, with one carbon credit equivalent to one metric ton of CO_2 equivalent. In a 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.[60] Farmers and ranchers in certain areas can participate in VCMs that credit them for implementing practices such as applying compost, growing cover crops, reducing tillage, or de-watering manure to use as a soil amendment. Companies and other emitters can purchase those credits from the farmers or ranchers.

A well-functioning VCM 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 either permanent, or of known duration. Activities are only considered "additional" if the farmer was unlikely to do them independently. Carbon sequestered for a carbon credit is typically permanent, and steps should be taken to mitigate reversals.[61] The multi-step Measuring, Monitoring, Reporting, and Verification (MMRV) process typically includes measuring the amount of GHG emissions reduced by a specific mitigation activity over a period, including sampling or modeling; monitoring the project implementation; recording all activities; and presenting these findings to an accredited third party for verification. Generally, third parties verify overall project implementation so that the results can be certified by the market's rules, and a carbon credit can be issued.

Case Study: Carbon Farm Planning for Climate Resilience

Project Funding Program: Conservation Agriculture Planning Grants Program
Planning Activity: Carbon Farm Plan
Awarded Organization: Lomita Farm
Award Year: 2023

Project Implementation County: Yolo

Dr. Jackelyn Lundy at Lomita Farm

Dr. Jackelyn Lundy has owned Lomita Farm for 43 years, stewarding the land with a mission to maintain long-term, sustainable organic systems. She was also the Director of the UC Santa Cruz Farm and Garden at the Center for Agroecology and the Associate Director of an 1,800-acre farm and environmental program at Hidden Villa. Over the years, Dr. Lundy has observed many changes on and around her farm, including depletion of groundwater resources. She has been disheartened to see that the extreme weather events even killed native hedgerows that have historically been resilient to environmental fluctuations. Dr. Lundy found she needed to irrigate mature plants, including a 40-year-old oak tree that wilted during a sustained heat wave. As a result of increased temperatures and extreme heat events, she has both reduced and eliminated irrigation to parts of her farm, as well as incorporated more water-wise environmental services.

Dr. Lundy was awarded a grant through the CDFA Office of Agricultural Resilience and Sustainability's **Conservation Agriculture Planning Grants Program** (CAPGP). This program is designed to fund the development of plans to help farmers and ranchers identify actions for climate change mitigation and on-farm adaptation. Dr. Lundy received technical assistance from Yolo Regional Conservation District and the UCANR Climate Smart Agriculture Program to support the development of a carbon farm plan, which includes actions and recommendations specific to Lomita Farm's cropping and livestock systems. The carbon farm plan also includes quantification of the carbon benefits of her plan.

While Dr. Lundy would potentially be interested in participating in a carbon market, the current barrier to entry for small-scale farmers is too high. Dr. Lundy speculated about changes to the current systems, such as including a third-party certification program to help mitigate the cost of certification, making small-scale operations more financially viable for credit brokers, and increasing the total amount of credits available to be sold.

*"**CAPGP** has helped me improve my on-farm decision-making and to do more **long-term planning** for my farm…. Policymakers, the [agricultural] community, and the public should know that there are some **important win-win opportunities** for those in [agriculture] who can take advantage of on-farm carbon sequestration and the carbon market. Farmers can get passive income from their existing farming systems and can increase this income by **designing and expanding** their **carbon sinks**."*

– Dr. Jackelyn Lundy

Quantification Challenges

There are various challenges with the current state of voluntary carbon markets for the agricultural industry.[62] Quantification of the GHG emissions reductions of climate-smart agricultural practices is challenging due to the dynamic nature of practice management, crop types, and varying soil and climatic conditions. These factors can affect the permanence of stored carbon and make direct measurement of GHG fluxes and/or carbon storage difficult and expensive.[63] The storage of carbon in soil is dependent on the recalcitrance (resistance to decomposition) of carbon added, and on the avoidance of field management that would accelerate its decomposition. Even if a majority of stored carbon can be physically or chemically protected under a certain set of environmental and management conditions, changes to the management conditions or persistent, unexpected climatic conditions, could make the carbon more accessible to microbial "attack" (decomposition) and thus subject to re-release into the atmosphere. As such, agricultural soil carbon offsets have an inherent limitation, which is that carbon sequestered in the soil has a wide range of storage times within the soil.

Agriculture-related voluntary carbon market protocols often rely upon site-specific sampling and modelling approaches to estimate GHG reductions. Sufficient sampling of soils and biomass to meet the accepted level of rigor for credits can be time-intensive, require specific field and laboratory skills, and can be costly. This is especially true when agricultural emissions credits are contingent on methane or nitrous oxide emissions changes. These two gases form the most significant GHGs emitted from agricultural activities in California, and "carbon credits" can be sold that depend on the carbon equivalents from reducing their emissions.[64] However, they are typically difficult to monitor directly; instead, considerable research has been done to model their emissions under a range of management and climatic conditions, so those conditions can be monitored and verified as a proxy for direct measurements. On the positive side, however, avoided emissions of these GHGs are not subject to a "duration" question like for carbon sequestered in the soil.

Key Definitions

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) – 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.

Consequently, modeling is often used for quantification. 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, long-term, and site-specific data for soils, weather, and crop management to build confidence in the model results. While not every site requires detailed information for a model, unique management or site-specific qualities should be incorporated into model validation. Thus, in California, where agricultural regions span a wide range of soil types, climatic conditions, and hundreds of crop types, validating models can be time and resource intensive. Both validation and monitoring costs can ultimately reduce the revenue available from carbon credits. When these costs are subtracted from the payment received by the farmer, as is typically the case, the final payment received can be lowered considerably and often does not meet the costs of farmers' efforts to implement the practice. This is particularly the case for small and diversified farms.

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. In the VCM context it typically refers to information that can be obtained from satellite-borne cameras and sensors. Remote sensing techniques can improve uncertainty and reduce reliance on extensive management records; however, more research is required for training and ground-truthing of remote sensing data inferences for use in crediting markets. Furthermore, collection of and access to remotely sensed data that is appropriate for small-scale, diversified specialty crop producers is challenging. Therefore, different pathways for support of climate-smart practice implementation are needed to accommodate such MMRV challenges for California producers.

Grower Hesitation

While many farmers and ranchers are familiar with the concept of voluntary carbon markets, few are participating. First, the adoption of new practices carries inherent risk. Farmers have limited and unpredictable financial resources, so unless the long-term benefits of participation will be appreciable, and the financial conditions involved in participation are clear, farmers may not be willing to engage in any carbon market participation that does not fully cover their additional costs, including the time to manage it.

As a case in point, one survey of farmers in the Midwest found that overall, they 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. Only three percent showed active interest in carbon market participation, while the rest indicated they were not ready to participate. A majority (59 percent) said they would participate in carbon markets if they were offered greater incentives.[65]

Similarly, another study surveyed both conventional and organic farmers who were participating and not participating in agricultural carbon markets.[66] All the participating farmers indicated that the prices of carbon credits were too low, and that the paperwork burden was too high. The study also noted that many non-participating farmers felt it was unfair that carbon markets were built on an industrial monocrop model that could not be easily applied to their small, diversified farms. This research underscores the fact that current carbon markets tend to be an option only for farmers and ranchers with significant resources and/or those who operate large, non-diversified operations. Simultaneously, the study calls attention to the work needed to better enable access for underserved and lower-resource farmers and ranchers and to develop new funding models for these producers.

Stakeholder Feedback

Stakeholders want to see markets and MMRV improvements that can fit and benefit small-scale and/or diversified operations. Especially exploring alternative, more effective incentive models—such as direct grants, cost-share programs, opt-out fees at businesses, or ecosystem service payments.

As part of this, stakeholders would like to see state-sponsored protocols, especially addressing additionality and permanence, and be lower-cost with accessible verification methods for credit generating markets.

Lastly, through this effort stakeholders would like to see how the state can support manufacturers to uplift climate-smart, California products.

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.[67]

1.5.1 Expand pathways to increase investment in climate-smart agriculture.

Goal 3: Support Economic Development

To achieve California's ambitious climate goals, it is not enough to just improve voluntary carbon markets' operations; we need to smooth existing financing and incentive pathways and explore new resources to grapple with the MMRV challenges mentioned above. The standardization of existing VCM protocols to produce more transparent, high-quality carbon and GHG credits could take several years. However, building and maintaining soil health is critical to the state's climate strategy, and we can use parallel pathways to invest in our soil health instead of waiting for the development of rigorous MMRV standards for VCMs.

Many non-governmental organizations and corporations are interested in funding climate-smart agriculture practices adoption and implementation. There are different motives for this interest; some funders aim for public recognition that their organizations or companies are climate friendly; others are looking to label the product they are selling as produced using climate-smart agriculture practices. Other organizations have declared climate targets and require specific quantification procedures to prove climate benefits that they are financially supporting. One example of an existing effort in this space is through nonprofit-private partnerships with Zero Foodprint, where cost share from consumers and businesses provide funds to the producers in the supply chain to implement climate smart agricultural practices.[68]

To enable these various pathways, it is necessary to advance not only improvements to the MMRV components of carbon or ecosystem service crediting markets, strengthening their validity, but also to improve and guide MMRV associated with less rigorous climate or ecosystem goals. In all these examples, MMRV requirements should

align with the end goal. Establishing guidelines for these requirements would boost credibility and prevent greenwashing. Table 4 summarizes support pathways that vary in verification rigor and end goals.

CDFA is currently working with sister agencies, including CARB and CNRA, to better understand opportunities for increasing investment in climate-smart agriculture, to identify pathways for future actions and to coordinate these efforts across multiple scales for multiple purposes. Working through the multiple pathways described above, some may expand access to current voluntary carbon markets, while other pathways would explore new routes to funding climate-smart agriculture.

- **Climate-Smart Labeling:** The creation of labels that signal a product was produced using climate-smart/regenerative agricultural practices could help create a product with higher market value, and more broadly raise consumer awareness of this group of practices. One of the advantages of a label would be the inclusion of growers who have been long-term practitioners. Often incentive programs or voluntary markets require new implementation, which would exclude those growers who are already utilizing climate-smart agricultural practices. Certain conventional agriculture practices, carry a risk of soil health deterioration, and soil health requires ongoing maintenance. A major goal of a climate-smart label would be to support farmers to continuously invest in soil health maintenance that is critical to resilience. The major goal of a climate-smart label is to maintain soil and/or ecosystem health across a wide range of agricultural management systems. Supply-chain actors may prefer funding or cost-share for practice implementation, as they could then market their products labeled as "climate-smart." Some states are already using this mechanism to maintain soil health. For example, the Saving Tomorrow's Agriculture Resources (STAR) program operates in Colorado, Illinois, Indiana, Iowa, Missouri, New Mexico, Utah and Washington. Farmers in these states can submit documentation that they have implemented climate-smart practices to an online platform, which can then be referenced by corporations or retailers who in turn offer rewards like higher prices for their products.
- **Climate-smart Certification:** This type of certification can help standardize what is considered a climate-smart agricultural practice and improve tracking of the implementation of these practices by calculating benefits. Several certifications already exist for U.S. markets, but a California certification could be aligned with state standards and capitalize on California agriculture's trusted reputation, and may ultimately result in premium prices for producers.[69] Some organizations within the state are already streamlining MMRV procedures for climate-smart products and have developed tools for tracking such activities and calculating the climate benefits of practice adoption.
- **Broadly Reward Ecosystem Services:** Valuing the broad suite of ecosystem benefits that climate-smart agriculture can deliver beyond carbon could better enable farmers and ranchers to access financial rewards for using these practices, because ecosystem service markets are more likely to rely on data about management activities as opposed to complicated soil carbon testing. For example, a nutrient tracking tool could be used to calculate water quality and quantity improvement benefits in response to climate-smart agricultural practices adoption. The State of Maryland has adopted such a system to pay for water quality and water quantity benefits.
- **Corporate Reporting:** Another avenue to encourage climate-smart practices and compensate producers for their ecosystem services is through insetting. Carbon insetting involves companies with sustainability commitments investing in emissions reductions or carbon removals within their own value chain.[70] Some companies also measure and track environmental metrics and compensate farmers for these outcomes.[71]

  With the passage in 2023 of the Climate Corporate Data Accountability Act (SB 253), the state of California is ramping up its mandatory corporate climate reporting. This 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.
- **Registries for Carbon Credit Projects:** Registries enlisting potential carbon credit projects can reduce barriers for both project implementers and those seeking to purchase credits. The Carbon Sequestration Resiliency Project Registry, created by SB 27 (Skinner, 2021), is intended to facilitate private funding of nature-based and direct air capture projects that deliver on California's climate goals.[72] Registries like this one could provide a potential opportunity to list climate smart agriculture projects, or even to aggregate projects happening on multiple small farms to reduce their collective MMRV reporting workload.
- **Uplifting MMRV Platforms, Programs, and Registries that cater to California:** Current MMRV protocols, platforms, and programs should be assessed to facilitate and ensure the integrity of locally active voluntary carbon markets and other programs which seek to provide payments for ecosystem services, while also allowing California's myriad crop types, farming systems, and diverse producers and farm sizes to participate. One example of a California-suited protocol could include "regional projects" with sampling designs to buffer against soil and climate variability and enable smaller farm participation.[73] Ideally, data collection would be standardized to enable sharing and dissemination across data platforms while ensuring confidentiality.[74] Identifying and supporting MMRV platforms, programs, and registries that fit California's farming operations and growing environments can also attract support from philanthropies, local governments, and other state agencies with carbon or ecosystem goals.

Stakeholder Feedback

Stakeholders indicated that RCD Regional Hubs can offer structure for locally- and regionally-determined strategies for climate resilience.

1.5.2 Increase Technical Assistance for investments in climate-smart agriculture.

Goal 1: Improve the Bottom Line for Farmers

The federal Growing Climate Solutions Act of 2022 authorized the development of a Greenhouse Gas Technical Assistance Provider and Third-Party Verifier Program that would have listed qualified technical assistance providers and third-party verifiers for growers to contact. California could continue this work by building on our current technical assistance provider networks. Consistent and regionally appropriate technical assistance by experts trained in the implementation, monitoring, and verification protocols of VCMs or other programs that provide payments for ecosystem services will be essential to widespread adoption of climate-smart agricultural practices. Strengthening the TA workforce is also crucial to the success of the other financing models discussed in this section (payments for ecosystem services, climate-smart certification, public registries) and provides secondary benefits such as reaching underserved producers, helping state programs disseminate funding, and providing training and education to farmers and ranchers."

Support System	Goals	MMRV Requisites	Likely Procedures for MMRV	Expected Funders	Marketing Privilege
Implementation based	Preventing soil health deterioration on small and diversified farms where rigorous MMRV is very onerous	Less rigorous MMRV. More focus on implementation	Verification of practices implementation by checking documents and geotagged photos	Public-private cost share, supply chain actors	Label
Outcome-/ ecosystem services- based payments	Continuing soil health maintenance with some calculations of soil health and climate benefits	Medium MMRV standards for calculating ecosystem services and climate benefits	Tools, online software, and databases for practice benefit calculations	Philanthropists, supply chain actors	Certificate
Market carbon credit	For achieving carbon sequestration and/or GHG emission reductions	Very strict MMRV standards as these involve offsets of GHG emissions elsewhere	Registry protocols, which can be overly onerous for many CA farmers at present	Corporations/ philanthropists	Carbon credit

Table 4: Pathways to invest in climate-smart agriculture adoption with different levels of MMRV requirements

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.[75]

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 Uplift existing technical assistance pathways.

Goal 1: Improve the Bottom Line for Farmers

In 2018, AB 2377 established the Climate Smart Agriculture Technical Assistance (CSA TA) program, which requires that at least 5 percent, but not more than 20 percent, of the annual budget for the AMMP, SWEEP, and Healthy Soils Program be directed for the CSA TA or indirectly through a block grant program that includes funding for technical assistance) program and prioritize 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. Not only does this support increase the overall impact of investments in Climate Smart Agriculture Incentive programs but it allows for a greater diversity of farmers and ranchers to apply for and access financial assistance. Since 2021, CSA TA has awarded grants to six TA providers for AMMP, 40 grants to TA providers for Healthy Soils Program, and 37 grants to TA providers for SWEEP. While the CSA TA provides important investment, high incentive program oversubscription and low numbers of TA applications (especially for CDFA's methane reduction programs) reveal a continued and significant demand technical assistance providers.

Stakeholder Feedback

Stakeholders would like to see technical assistance successes tracked over time.

Additionally, the Fertilizer Research and Education Program (FREP) has supported technical assistance for growers to increase nitrogen and irrigation efficiency on farms through the Nitrogen and Irrigation Initiative (NII), which was funded by $5 million in federal and state grants. The NII is a collaborative partnership between CDFA, UCANR, and UC Davis to help San Joaquin Valley and Central Coast growers and crop consultants implement improved nitrogen and irrigation management practices. Farm advisors and their staff are working with growers to deliver research-based, practical information that can reduce fertilizer and irrigation inputs, mitigate groundwater nitrate contamination, and help growers comply with water quality regulations. Technical assistance is provided through on-farm consultations, workshops, field trials, on-farm demonstrations, and educational resources. A team of UC Davis social scientists is also supporting the project by collecting metrics on grower participation, learning and adoption of best management practices and assisting with an iterative program evaluation process.

CDFA has a technical assistance agreement with UCANR's Climate Smart Agricultural Program which offers technical assistance for CDFA incentive programs through the Community Education Specialists. These technical assistance providers can fill-in support for farmers and ranchers outside of funding allocations for specific CDFA programs as the agreement is not connected to specific program solicitations. Since 2019, the Climate Smart Agriculture Team has provided technical assistance, including many one-on-one consultations, with more than 1,300 farmers and ranchers across 25 counties in the state.[76] This kind of direct-to-producer assistance is critical for building local knowledge as well as addressing access and language barriers for underserved and minority populations. The success of this program is an important example of how continuous and regional technical assistance can bolster widespread adoption of climate-smart agriculture.

Stakeholder Feedback

Stakeholders noted that consistent funding for technical assistance is important for maintaining trusted relationships with producers, ensuring timely application support, enabling follow-through on practice implementation, providing on-the-job training and continuing education for TA providers, and supporting regular outreach to tribes and small producers and producers of color.

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. In 2019, CDFA's Inspection Services Division established the Food Safety Modernization Act (FSMA) Technical Assistance Program (TAP) to provide educational resources to small-scale produce farms to support compliance with the federal FSMA Produce Safety Rule (PSR), which sets standards for the growing, harvesting, packing, and holding of fruits and vegetables grown for human consumption.

Under the Inspection and Compliance Branch, TAP works with UC Cooperative Extension Specialists, Advisors and Community Educators who have expertise in on-farm food safety and production practices. TAP offers a range of resources including information fact sheets, online learning platforms, in-person workshops, and on-farm TA. Within these are resources tailored to small-scale growers and their unique needs. Climate change increases extreme weather events that may present a risk to produce (such as floods), therefore, ensuring produce safety is a critical component for a safe, healthy, and resilient food system.

More work is required to transfer known information to landowners, suppliers, processors, retailers, and consumers regarding how factors such as adjacent lands and presence of wild or domesticated animals, soil health and soil amendments, sources of irrigation or post-harvest-use water interconnect to on-farm food safety for various crops and commodities. Information regarding holistic land management approaches that create climate-smart and food-safe products requires continued research, constant compilation, research translation, 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.

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.

Stakeholder Feedback

Stakeholders noted that RCDs are critical for providing boots-on-the-ground technical assistance at the local level.

1.6.2 Build partnerships to foster multifaceted technical assistance capacity.

Goal 1: Improve the Bottom Line for Farmers

Meeting the TA demands in California requires a coordinated effort throughout a network of organizations and entities engaging with TA across the state. In 2022, the California Conservation Planning Partnership (C2P2) was established as a joint effort between the USDA Natural Resources Conservation Service (NRCS), UC ANR, the California Association of Resource Conservation Districts (CA RCD) and CDFA to coordinate resources and efforts surrounding the delivery of science-based TA. The key pillars of the partnership include the promotion of equity in the delivery of TA, accelerating conservation innovation and practice adoption, coordination of services and programs, building technical capacity, maintaining consistent and locally led TA, and amplifying outreach to increase communication and collective impact.

Over the last year, working groups for C2P2 have convened to advance conservation innovation and practice adoption, maintain consistent locally let technical assistance and also extend technical assistance, and lastly build technical assistance capacity and advance trainings. In 2024, CDFA on-boarded a Technical Assistance Coordinator to support the development of a technical assistance workforce, improve access to and quality of TA for California's farmers and ranchers, and coordinate working groups for C2P2.

Stakeholder Feedback

Stakeholders indicate that nonprofits and community development corporations are also well-suited to develop training and career pathways, particularly for farmworkers with limited traditional educational backgrounds.

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

Goal 3: Support Economic Development

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 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 its 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.

1.6.4 Promote Jobs First programs to increase the agricultural workforce.

Goal 3: Support Economic Development

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 $86 million to food systems programs to expand Career Technical Education programs in schools and on farms, and the program reaches 49 percent of all California 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 respond 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 five California Native American tribes to provide educational and career pathways for native youth and young adults while preserving and protecting native land.[77] 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.

Case Study: Equitable Training as a Catalyst for Upward Mobility

Project Funding Program: Beginning Farmer and Farmworker Training Program

Awarded Organization: Mixteco Indigenous Community Organizing Project

Award Year: Awarded 2022 (Completed January 2025)

Project Implementation Counties: Ventura, Santa Barbara

CDFA Farm Equity Advisor Thea Rittenhouse meeting with the Mixtec/Indigenous Community Organizing Project team.

The **Beginning Farmer and Farmworker Training Program** (BFFTP) supports new and existing beginning farmer training and agricultural apprenticeship programs in California. It is aimed at helping strengthen networks and develop strategies to overcome barriers including lack of education and training, prioritizing direct access to historically underserved groups to ensure the transition to farm ownership is successful.

Juvenal Solano is the Workforce Programs Coordinator for the Mixtec/Indigenous Community Organizing Project (MICOP), an organization that seeks to provide information on labor rights, job training, community organizing, and cultural preservation in the seven native, pre-Hispanic languages spoken by farmers in the Central Coast region.

By providing access to continuous learning, MICOP's various initiatives have helped farm workers gain confidence in asserting their rights, increasing their knowledge of workplace health and safety and ultimately obtaining certifications that they translated into getting higher paying jobs; this underlines the strong upward mobility potential of equitably designed training programs. These skills can help mitigate the physical and mental pressures compounded by climate change that are faced especially by these disadvantaged communities. Funding from the BFFTP helps MICOP to continue "building leaders of tomorrow…. In the Indigenous communities … there is a community practice known as TEQUIO, which consists of voluntary and unpaid collaboration by the community itself to carry out works and actions for the common good. Through this collective work, community identity and social and cultural ties are being strengthened for our future generations."

*"**Our people** live around **agriculture**, and everything related to climate change affects our communities directly…. For us, **'climate resilience'** has a profound meaning because we are the peoples of the rain (Mixtec) and the clouds (Zapotec). **Our identity, our stories, and our ways of life** are intimately connected to the water cycle, Mother Earth, and the skies. Climate resilience is not only about resisting the impacts of climate change, but also about **keeping alive the sacred relationship with nature that gives us life**."*

– Juvenal Solano and MICOP

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 agtech 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.

Rice Cultivation Credits

In the San Joaquin-Sacramento River Delta, 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 car-bon markets) using their California Deltaic and Coastal Wetlands Restoration Methodology. Likewise, with funding from the Delta Conservancy, the Metropolitan Water District of Southern California (MWD) is converting the Delta's Webb tract to a landscape mosaic (1,500 acres rice, 3,000 acres managed wetlands). MWD will validate these projects with ACR. The Delta Conservancy has also funded a TNC program to enroll small farmers for up to 5,000 acres of rice conversion. All of these projects address land sub-sidence and related carbon dioxide emissions while improving the islands' long-term economic viability and climate resilience.

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. CDFA regulates the direct marketing of agricultural products through Certified Farmers Markets, allowing small farmers to market their products without the added expenses of commercial preparation and providing consumers with the opportunity to meet the farmer and learn how their food supply is produced. There are approximately 655 certified farmers' markets and approximately 2,700 certified producers.

1.7.1 Expand the CA Grown Marketing Campaign to expand awareness of climate-smart practices and the programs that support them.

Goal 3: Support Economic Development

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 raise awareness about climate-smart agricultural practices and the programs that support practices adoption, such as the Healthy Soils Program, into the existing CA Grown campaign.

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

Goal 3: Support Economic Development

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.

Case Study: CDFA Secretary Meets with International Partners for Climate Smart Collaborations

To build global climate resilience through collaboration, the Secretary of the California Department of Food and Agriculture, Karen Ross, meets regularly with international partners to exchange knowledge and strengthen trade relationships. These meetings bring California together with many other nations and subnational governments focused on building agricultural resilience through climate and economic action.

In July 2024, Secretary Ross joined Governor Newsom in meeting with a **New Zealand delegation** to discuss nature-based solutions, climate smart agriculture, and the circular economy, with future collaboration intended to address livestock methane emissions reductions and sustainable pest management.

Secretary Ross **traveled to Vietnam** in September 2024 as part of a USDA trade mission in celebration of the one-year anniversary of the U.S.-Vietnam Comprehensive Strategic Partnership. The convening offered opportunities for U.S. companies to engage face-to-face with Vietnamese buyers to build new trade linkages, strengthen existing partnerships, observe U.S. products in the marketplace, and identify emerging trends in Vietnam's fast-changing markets.

CDFA Secretary Ross met with Vietnamese representatives in September 2024.

CDFA Secretary Ross speaks with former USDA Secretary Tom Vilsack and other delegates from around the world at the United Nations Framework Convention on Climate Change Conference of the Parties 28 (UNFCCC COP28) in Dubai, United Arab Emirates in December 2023.

Secretary Ross **visited Peru** in October 2024, meeting with government officials, academics, and growers to discuss shared climate change challenges. Secretary Ross noted that "the work that is occurring on farms in Peru is impressive… Through this work, Peru is changing the desert landscape and building soils for food production."

In Summer 2025, Secretary Ross **visited Brazil** to meet with several groups at the public-private interface progressing Brazil's leadership on agricultural biologicals and integrated pest management. Further collaboration will be done in the coming years to integrate international responses to mitigate the impacts of climate change.

CDFA Secretary Ross speaks with former USDA Secretary Tom Vilsack and other delegates from around the world at the United Nations Framework Convention on Climate Change Conference of the Parties 28 (UNFCCC COP28) in Dubai, United Arab Emirates in December 2023.

*"**International partnerships** are **crucial** for building **climate resilience** in California and globally. With constant **innovation** all over the world, it is important to be able to **learn from other governments, academic institutions, the private sector, and growers**, sharing our knowledge to **catalyze creative solutions** that drive **global progress** on **global problems**."*

– CDFA Secretary Karen Ross

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

Goal 3: Support Economic Development

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 understanding) 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.

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 Pritzker, 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	Existing Initiatives
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.	1: Improve the Bottom Line for Farmers	USDA RMA	Agriculture Risk Coverage, Micro Farm Crop Insurance option, Whole-farm Revenue Protection, Parametric Insurance Pilot
1.1.2 Effectively promote and deploy the California Underserved and Small Producers (CUSP) program.	1: Improve the Bottom Line for Farmers	CDFA	California Underserved and Small Producers (CUSP)
1.2 Reduce workload associated with meeting or exceeding regulatory goals.			
1.2.1 Simplify and streamline regulatory compliance reporting.	1: Improve the Bottom Line for Farmers	All	CDFA and CalEPA Regulatory Alignment Study
1.3 Invest in research and development to provide new options for building resilience on farms.			
1.3.1 Invest in research and development of agtech to optimize inputs and improve efficiency.	1: Improve the Bottom Line for Farmers	GoBiz	The VINE, F3 (Farms, Food, Future) Initiative
1.3.2 Ensure equitable deployment of technical tools and support for small and under-resourced farmers.	1: Improve the Bottom Line for Farmers	CDFA	California Jobs First Economic Blueprint
1.3.3 Provide infrastructure support for broadband upgrades.	3: Support Economic Development	CPUC, CDT (OBDL)	Broadband for All, California Broadband Council
1.3.4 Invest in R&D for climate adaptive, heat- and drought-resistant crop varieties.	3: Support Economic Development	CDFA	Specialty Crop Block Grant Program

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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.	3: Support Economic Development	CDFA	Resilience Food Systems Infrastructure Program, Farm to Community Food Hubs Program, California Farm to School Incubator Grant Program, Planting the Seed: Farm to School Roadmap for Success
1.4.2 The circular bioeconomy: supporting the creation of new income streams for farmers.	1: Improve the Bottom Line for Farmers	CalRecycle, GoBiz	California State Economic Blueprint, BEAM Circular, Conservation Reserve Program
1.4.3 Ensure the highest and best use of diverted organics to animal feed while ensuring safety	3: Support Economic Development	CDFA	Commercial Feed Regulatory Program, Safe Animal Feed Education Program
1.5 Increasing investment in climate-smart agriculture.			
1.5.1 Expanding pathways to increase investment in climate-smart agriculture.	3: Support Economic Development	All	Carbon Sequestration and Climate Resiliency Project Registry
1.5.2 Increase Technical Assistance for investments in climate-smart agriculture.	1: Improve the Bottom Line for Farmers	CDFA	Climate Smart Agriculture Technical Assistance (CSA TA)
1.6 Support workforce development through programs and training.			
1.6.1 Uplift existing technical assistance pathways.	1: Improve the Bottom Line for Farmers	CDFA	Climate Smart Agriculture Technical Assistance (CSA TA), Climate Smart Agricultural Program
1.6.2 Build partnerships to foster a multifaceted technical assistance capacity.	1: Improve the Bottom Line for Farmers	CDFA	California Conservation Planning Partnership (C2P2)
1.6.3 Coordinate with California higher education systems to expand training and career development in agriculture.	3: Support Economic Development	CDFA	CNRA Workforce and Economic Impact Study, CSU Chico TAP Certification Program, AgTEC Workforce Program, Farmworker Advancement Program, California Jobs First Initiative

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
1.6.4 Promote Jobs First programs to increase the agricultural workforce.	3: Support Economic Development	GoBiz	California Jobs First Economic Blueprint, Jobs First Council, CalAgPlate Grant Program, Farm to School, Agricultural Education Unit, California State Plan for Career Technical Education, California Conservation Corps, California Climate Action Corps, F3 Initiative
1.7 Expand climate-smart agricultural marketing efforts.			
1.7.1 Expand the CA Grown Marketing Campaign to include climate-smart products.	3: Support Economic Development	CDFA	CA Grown
1.7.2 Expand marketing efforts to highlight products from the circular economy.	3: Support Economic Development	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: Support Economic Development	CDFA	UNFCCC COP, Subnational Methane Action Coalition (SMAC), Mediterrean Climate Action Partnership (MCAP), Under2 Coalition, American is All In, U.S. Climate Alliance, Numerous Bilateral and Multilateral Climate Agreements

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

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

Water is critical for California's agriculture, reaching the state's farmers and ranchers through snowpack-fed surface water, groundwater, and recycled sources all connected through extensive infrastructure. However, climate change is increasingly threatening both water supply and reliability. While California agriculture depends on secure, clean water, it can also support long-term water resilience through efficient use, groundwater recharge, ecosystem protection, and improved management.

This chapter includes strategies that reduce demand, increase efficiency, secure groundwater quality and supplies, protect freshwater ecosystems, and build needed infrastructure to ensure long-term water resilience and continued support for farmers and ranchers.

Context

Agriculture is the largest user of water in the State, consuming approximately 40 percent of the state's water across millions of acres.[78]

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.[79] 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 demand for 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: Adapting 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 watersheds, safeguarding existing infrastructure, contributing to groundwater recharge, and using water efficiently.[80]

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.[81] 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.[82] 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.[83]

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 sources such as groundwater, recycled water, and desalinated water, which, without intervention to maintain and expand these water sources' volumes, would threaten water security for the state.[84]

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 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.[85]

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.[86] 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.[87]

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, reduce water storage capacity, increase the chances of flooding, impair agriculture in the long term.[88] During the 2022 drought, it is estimated that irrigated 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.[89] Scientists estimate that drought could result in $3 billion in economic losses to agriculture annually.[90] (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.[91] 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 causing 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.

Stakeholder Feedback

Stakeholders indicated groundwater sustainability agencies, third-party organizations, and water quality coalitions are all important collaborators at the local and regional level.

Stakeholders would like to see continued regulatory alignment work that strengthens relationships between CDFA and SWRCB, expands to include more state agencies, and moves towards action on alignment opportunities, especially if these actions bolster the adoption of climate-smart practices.

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.[92] 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.[93]

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 natural habitat and/or croplands and displace and kill wildlife and farm animals.[94] Flood water can contain sewage microorganisms or other contaminants, compromising the safety of exposed crops.[95] Further, it is recommended that farmland be left fallow for 30-60 days after flooding to ensure that the land is cleared of pathogens.[96] 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.[97]

Chapter 2: Ensure a Water System for Agricultural Resilience in a Hotter, Drier Future

Water Quality

In addition to water supply, water quality is critical for humans, wildlife, livestock, and plants to thrive. Overapplication of fertilizer can lead to excess nitrogen and other nutrients leaching into the water supply and can lead to negative health effects. Even efficient fertilizer application and management may lead to nitrogen and other nutrient leaching into groundwaters where soils are permeable and groundwater tables are shallow.

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, which can impact the health and well-being of people who come into contact with it. Groundwater management practices have, in some areas, degraded water quality by altering aquifer chemistry, increasing concentrations of key constituents such as nutrients, arsenic, and total dissolved solids, and contributing to contaminant plume migration. Additionally, reduced flow in the Sacramento-San Joaquin Delta region can increase the risk of saltwater intrusion into freshwater zones which are part of the water delivery system for Californians across the state.[98]

Elevated salinity in surface water and groundwater are increasing problems affecting much of California. Salinity impacts to agriculture will be worsened by climate change. Higher temperatures and periods of drought will increase reliance on groundwater, which often has higher salinity. Increased use of groundwater further concentrates salt in soils, reducing productivity. In the Central Valley, approximately 1.5 million acres of irrigated land are salinity-impaired and 250,000 acres have been taken out of production due to salt accumulation. Model projections indicate that within the century, salinity concentrations in parts of the Central Valley will accelerate to the point where groundwater will be unusable as a non-blended supply for agriculture.

Strategies and Actions

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

California Water Plan

Water management in California is a coordinated effort between state, federal, and local governments, local water districts, and local and regional entities. California's statewide strategic plan for guiding water managers and decision-makers 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 legislation and strategies such as the Sustainable Groundwater Management Act, the Water Resilience Portfolio, and California's Water Supply Strategy.

The California Water Plan in required by California Water Code and serves as a master plan for the sustainable and equitable management of water resources in the state and serves to guide the orderly and coordinated control, protection, conservation, development, management, and efficient utilization of the state's water resources. The California Water Plan Update 2023 addresses this goal at multiple scales, from statewide to watershed level, and features three themes—climate urgency, watershed resilience, and equity—that frame key challenges, priorities, and desired outcomes. Through these themes, the Plan outlines recommendations that seek to build an equitable and resilient future for the state's watersheds, water systems, and communities.[99]

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.

SB 72 (2025) establishes new statutory mandates for the California Water Plan that will be incorporated in future California Water Plan updates (CWP 2028 and CWP 2033). SB 72 requires the California Water Plan to estimate statewide, long-term water supply targets for urban, agricultural, and environmental uses. SB 72 also requires the California Water Plan to recommend programs, policies, and facilities to meet the new water supply targets. Accordingly, this Climate Resilience Strategy for California Agriculture is intended to align with the evolving Water Plan as it is updated under SB 72.

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 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 works 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.

Stakeholder Feedback

Stakeholders would like to see consistent support for GSA projects that bolster groundwater supply, improve conveyance systems, and increase surface storage.

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 Statewide. 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 and developed groundwater sustainability plans that are required to include basic-specific measures to avoid undesirable results including consideration of drought conditions; specifically declining groundwater levels, depletion of groundwater storage, land subsidence, degradation of groundwater quality, depletion of interconnected surface waters, and saltwater intrusion. 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 can lead to the undesirable results aforementioned, resulting in major impacts on agricultural communities, including drying of local wells, deterioration of water quality, increased pumping costs,

and damages to infrastructure that impair agriculture in the long term.[100] By increasing technical assistance around water regulation and compliance for farmers, supporting monitoring efforts to improve irrigation and fertilizer use 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 SGMA regulations and navigate compliance.

Goal 1: Improve the Bottom Line for Farmers

DWR's Underrepresented Communities, California Tribes, and Small Farmers Groundwater Technical Assistance Program is working to determine the needs, risks, 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.[101]

During periods of groundwater recharge and reduced groundwater use, farmers may utilize alternate water sources for crop production on different sites. Food safety risks associated with agricultural water can vary based on factors such as source and application type. For example, open water sources such as canals or sprinklers may have a potential for more bird or wildlife contact than enclosed groundwater wells or subsurface drip systems. Therefore, education, outreach and technical assistance related to appropriate management of food safety risks associated with various agricultural water sources is valuable in conjunction with knowledge of water savings and GHG reductions. FSMA Produce Safety Rule Subpart E Agricultural Water was finalized recently in 2024 and presents a unique opportunity to build a robust technical assistance program that maximizes various co-benefits that can be associated with irrigation and other agricultural water uses such as post-harvest cooling.

Stakeholder Feedback

Stakeholders would like to see expanded coordination between CDFA and DWR to development strategies to support vulnerable growers whose production methods may need to change as a result of SGMA.

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

Goal 4: Provide Health and Environmental Benefits

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.[102] 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 4: Provide Health and Environmental Benefits

While it is the goal of SGMA to ensure that aquifers are brought back into balance through operating to sustainable yields and careful monitoring of water extraction, there could be 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 flood water resulting from precipitation events on working lands, like agricultural land (in this case, Agricultural-MAR), to prevent flooding in undesirable locations and allow the water to infiltrate and recharge groundwater aquifers. In Agricultural Managed Aquifer Recharge (Ag-MAR), spreading flood water is a secondary use, where the primary use is for growing crops.[103] For Ag-MAR, it is important to consider a number of factors including the permeability of the underlying geology, what infrastructure will be required to divert floodwater, potential impacts to groundwater quality, current and historic agricultural management practices, 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. DWR and CDFA have regular coordination meetings where topics such as our technical assistance program are discussed and efforts are coordinated.

Capturing and storing surface water, including floodwaters, usually requires an appropriative water right. However, greater coordination with landowners, 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.

Stakeholder Feedback

Stakeholders would like to see research to evaluate the feasibility of including dairies into groundwater recharge strategies.

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

Goal 4: Provide Health and Environmental Benefits

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

DWR's LandFlex program provided $25 million in grants to Groundwater Sustainability Agencies 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.[104] 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 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 farmland impacted by water scarcity, 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 as highlighted in the 2022 California's Water Supply Strategy, Adapting to a Hotter, Drier, Future. 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.

Stakeholder Feedback

Stakeholders are in support of policies and actions to improve water storage capacity and conveyance infrastructure to bolster water resilience and economic stability.

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: Support Economic Development

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 Action 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 groundwater. 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 3: Support Economic Development

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.

Critical to major infrastructure investments is consideration of local and isolated conveyance together to protect state-wide and regional water access and quality. In the Delta, this concept is referred to as dual conveyance and is integral to 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. This project is 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. Locally, infrastructure improvements such as levee improvements within the Delta are needed in accompaniment to the Delta Conveyance Project 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.[105]

One of the most critical challenges is land subsidence, which has damaged major water conveyance systems due to decades of groundwater overdraft in regions. Subsidence has damaged critical conveyance infrastructure like the Friant-Kern Canal, Delta-Mendota Canal, and California Aqueduct, making it harder for water to flow.[106] 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 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 with authorization for an additional $100 million in the next fiscal year 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, on-demand water delivery systems, pressurized pipeline water delivery, 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. One example of this is the South San Joaquin Irrigation District's pressurized irrigation service which allows growers more reliability and flexibility for irrigation timing. The continuation of research on water-use efficiency will help to further develop technologies that can be implemented to improve water conveyance infrastructure. The continuation of research on water-use efficiency will help to further develop technologies that can be implemented to improve water conveyance infrastructure. 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. CDFA's Fertilizer Research and Education Program funds research and education for growers to increase irrigation efficiency by supporting weather/based irrigation scheduling tools along with expanding education and support to assist growers with implementing these practices.

2.3 Improve watershed management and restore freshwater ecosystems.

Good watershed management is essential to freshwater ecosystem restoration because rivers, lakes, wetlands, and groundwater systems are shaped by everything that happens across the land draining into them. Effective management reduces sediment, nutrient, and pollutant runoff from agriculture, urban areas, and infrastructure, helping to restore water quality, natural flow regimes, and habitat conditions that aquatic species depend on. By protecting riparian zones, restoring floodplains, and managing water withdrawals at the basin scale, watershed approaches reconnect rivers to their landscapes, improve resilience to floods and droughts, and support biodiversity from microbes to fish and birds. In a changing climate, good watershed management also strengthens the capacity of freshwater ecosystems to adapt by enhancing groundwater recharge, moderating temperature extremes, and sustaining ecosystem services—such as clean drinking water, fisheries, and cultural values—that communities rely on.

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

Goal 4: Provide Health and Environmental Benefits

"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.[107] 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.[108]

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 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.[109] 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 4: Provide Health and Environmental Benefits

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 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.

Despite all of its benefits, riparian restoration often requires substantial resources to be successful. To help with this, 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.[110]

2.3.3 Promote efficient nutrient management to reduce nutrient loading from agricultural land.

Goal 4: Provide Health and Environmental Benefits

The development of the Haber-Bosch fixation process in 1908 gave humanity the ability to take unreactive nitrogen gas (N_2) from the atmosphere and transform 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.[111] 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.[112] Synthetic N fertilizer has supported about 4 billion people born since 1908.[113] However, overapplication of synthetic N fertilizers leads to reactive N loss into ecosystems, via leaching or runoff into water systems and/or release of greenhouse gases and other emissions that harm air quality.[114]

Agricultural leaching and runoff containing nitrogen enters groundwater, rivers, lakes, estuaries, and the marine environment, leading to environmental and human health challenges.[115] 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.[116] 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 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.[117] Groundwater bodies are impacted from elevated concentrations of pesticides, nitrates, and salts from irrigation and stormwater runoff transporting pollutants from agricultural lands.[118] This leads to drinking water contamination that can exceed safe standards for some communities in and around agricultural areas.[119] Recognizing agricultural runoff's crucial role in groundwater contamination and HABs and OAH, smart fertilizer practices, nitrogen and phosphorus load reductions, and watershed-level nutrient control may help to mitigate these challenges.

Furthermore, input-intensive farming can reduce soil nutrient availability, including nitrogen, which can lead farmers to increase their use of synthetic fertilizers over time.[120] In California, N_2O from crop growing and harvesting (including fertilizer application) in 2023 is 5.84 MMT CO_2 equivalent, which is almost 20 percent of all greenhouse gas emissions from agriculture in the state.[121]

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, riparian buffers or cover cropping, help farmers improve soil health, reduce input costs, and protect groundwater and waterways. These practices not only safeguard the water supply but also support the long-term sustainability and productivity of agricultural operations. Specifically, the transition to micro irrigation, along a gradient of control from sprinklers to subsurface drip, allows the application of lower amounts of fertilizer, especially of nitrogen, and dramatically lowers the emissions of the GHG nitrous oxide. It is for this reason that CDFA has integrated CARB-supported research to account for the nitrous oxide benefits of its SWEEP irrigation-system incentives.

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. The program supports the long-term sustainability of California's agricultural and natural resources by protecting water resources and encouraging nutrient management planning. Currently over 50,000 farms, comprising more than six million acres, are enrolled in waste discharge requirements for the program. The program has also enabled the formation of third-party Water Quality Coalitions, which have worked to improve agricultural operations impacts on water quality by helping their grower members comply with wastewater discharge requirements, conduct surface and groundwater data collection for monitoring quality, and prepare regional plans to address water quality programs.

CDFA's Fertilizer Research and Education Program (FREP) funds outreach and research projects on the environmentally safe and agronomically sound use and handling of fertilizing materials. FREP has funded over 280 research and education projects to improve knowledge and optimize fertilizer and irrigation use, aiming to minimize runoff, leaching, and contamination of surface and groundwater sources. This includes funding targeted research and providing technical assistance through the Nitrogen and Irrigation Initiative to support growers in meeting ILRP water quality regulations. FREP also offers free trainings for growers and Certified Crop Advisors on nitrogen and irrigation management that allow those who pass a corresponding exam to certify Irrigation and Nitrogen Management Plan (INMP) Worksheets as part of ILRP requirements.

In addition, FREP offers and regularly updates the California Crop Fertilization Guidelines, which offer fertilizer application recommendations by growth stage for 28 crops. The guidelines, which synthesize peer-reviewed journal articles and research done in California, are intended to provide growers and crop advisors with accurate and agronomically effective crop nutrient information that improve application efficiencies.

Stakeholder Feedback

Stakeholders recommended closer coordination between the Water Boards ILRP and CDFA, especially in data sharing, to ensure state agencies are working towards shared goals for soil health, nutrient management, and environmental quality and avoiding adding financial burdens to producers.

Stakeholders supported reducing ILRP reporting workload for small and diversified farmers while maintaining data collection standards.

Online decision support tool CropManage helps growers improve irrigation efficiency

In 2011, the Fertilizer Research and Education Program was one of the first programs to fund the development of the free online nitrogen and irrigation management decision-support tool for growers called CropManage. CropManage provides growers with recommendations for irrigation and fertilizer scheduling based on weather, satellite imagery, crop and soil type, evapotranspiration data, irrigation system efficiency and other related variables. The platform also allows growers to document irrigation and fertilizer applications over the growing season.[122] The goal of CropManage is to assist growers in matching nitrogen and irrigation applications to crop demand, which can improve efficiency, reduce costs and meet regulatory water quality requirements. Currently, CropManage supports over 30 commodities, including leafy greens, berries, and nut, forage and row crops, with more crops being added when there is both grower demand and California-based field trial data to support their inclusion.

The Nitrogen and Irrigation Initiative also supports the use of CropManage as a best management practice to improve nitrogen and water use efficiency by providing technical assistance to growers for field implementation. Farm advisors and their staff provide hands-on workshops to introduce the tool and help attendees learn how to add ranches, collect field data, and track water and nitrogen applications. They also meet with growers and fieldworkers to help install flow meters, conduct soil sampling, analyze N availability in the soil and irrigation water, enter data into CropManage and interpret fertilizer and irrigation recommendations. In addition, extension staff assist with troubleshooting issues and conduct side-by-side trials in growers' fields to demonstrate the water and fertilizer savings possible without sacrificing yield or quality when crops are grown according to CropManage recommendations compared to the grower's standard practice.

2.4 Continue improving on-farm water use efficiency.

Over the last several decades, California producers have made significant advances in on-farm water use efficiency and contributed to our state's reputation for leadership in this area. These advances are the result of farmer innovation, research and development in collaboration with our state's land grant universities, and industry investments. 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 research, technical assistance and training 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.

Stakeholder Feedback

Stakeholders felt that water efficiency was at the center of resiliency for agriculture, and more research and investment in water efficiency strategies, tools, and projects, as well as in grower technical assistance, is critical for farm survival.

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

Goal 1: Improve the Bottom Line for Farmers

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 District.

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

Goal 1: Improve the Bottom Line for Farmers

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.[123] Modeled increases in soil organic matter of three percent improved water benefits and decreased the impacts from climate change for almost all working lands.[124] 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.[125] These practices are described in depth in Chapter 10 on Soil Health and Chapter 11 on 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.

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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: Improve the Bottom Line for Farmers	CDFA	Underrepresented Communities, California Tribes, and Small Farmers Groundwater Technical Assistance Program
2.1.2 Support monitoring capabilities to improve our understanding of drivers of change.	4: Provide Health and Environmental Benefits	DWR	California Irrigation Management Information System (CIMIS)
2.1.3 Coordinate across agencies to develop new groundwater use and recharge strategies.	4: Provide Health and Environmental Benefits	DWR, SWRCB	Water Supply Strategy, Flood-Managed Aquifer Recharge (Flood-MAR), Streamlined processing for standard groundwater recharge rights
2.1.4 Work with water users to assist with groundwater use and recharge.	4: Provide Health and Environmental Benefits	DWR, DOC	LandFlex, Multibenefit Land Repurposing Program (MLRP)
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: Support Economic Development	CDFA	State Water Efficiency and Enhancement Program (SWEEP), Proposition 1 Water Storage Investment Program
2.2.2 Advance critical infrastructure projects for water conveyance.	3: Support Economic Development	DWR	Delta Conveyance Project, $100 million funding to restore capacity lost to land subsidence, Real-Time Data Direct Grant Program, Surface Water Ambient Monitoring Program, State Water Efficiency and Enhancement Program (SWEEP)

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
2.3 Improve watershed management and restore freshwater ecosystems.			
2.3.1 Promote ecologically appropriate prescribed grazing designed to improve ecosystem health in headwater areas.	4: Provide Health and Environmental Benefits	RMAC, Board of Forestry and Fire Protection	California's Nature Based Solutions Climate Targets, SB 675 (Limon, 2024)
2.3.2 Expand implementation of riparian zone restoration practices in agricultural land.	4: Provide Health and Environmental Benefits	DOC, WCB	California's Nature Based Solutions Climate Targets, Working Lands and Riparian Corridors Program, California Riparian Habitat Conservation Program, Healthy Soils Program
2.3.3 Promote efficient nutrient management to reduce nutrient loading from agricultural land	4: Provide Health and Environmental Benefits	CDFA, SWRCB	Irrigated Lands Regulatory Program, Fertilizer Research and Education Program (FREP)
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.	1: Improve the Bottom Line for Farmers	CDFA	State Water Efficiency and Enhancement Program (SWEEP), Water Efficiency and Technical Assistance (WETA), Agricultural Water Management Plans
2.4.2 Use nature-based solutions/ healthy soils practices to improve water-holding capacity and percolation on farm and ranch lands.	1: Improve the Bottom Line for Farmers	CDFA	Described in depth in Chapter 10 on Soil Health Practices and Chapter 11 on Ranching and Rangeland Management

3 Support Agricultural Workforce Wellbeing and Health

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

Despite California's globally significant agricultural economy, many agricultural communities face persistent social and economic challenges, including high levels of poverty, food insecurity, and educational and health disparities among farmers and farmworkers. Climate change is intensifying these inequities by increasing exposure to extreme heat, poor air quality, wildfire smoke, and dust. Building climate resilience across the agricultural workforce and communities is essential to enable people to safely adapt to, respond to, and recover from climate-driven impacts.

This chapter examines how California is working to create a safer and healthier agricultural workforce by strengthening heat and climate safety policies, investing in research and technology, and expanding programs that protect workers' physical and mental health. These efforts include improved heat illness standards, emergency protections, early warning tools such as CalHeatScore, research on on-farm safety, and expanded outreach and training for farmworkers. Together with investments in rural infrastructure, housing, community resilience, and emergency response facilities, these actions aim to protect agricultural workers from climate-related hazards while supporting a resilient and productive agricultural industry.

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, food insecurity, and access to clean and affordable drinking water.[126] 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 smoke from wildfire and dust.[127]

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.

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 in a hotter, drier climate.

Goal 4: Provide Health and Environmental Benefits

The state is already working to ensure that the agricultural workforce has policies in place to promote resilience, but there are additional protective 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.[128] 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 on tools for on-farm health and safety.

Goal 4: Provide Health and Environmental Benefits

The UC Davis Western Center for Agriculture Health and Safety (WCAHS) funds research for agricultural workforce safety and wellbeing. Staff conduct 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 Labor and Workforce Development Agency (LWDA) funds WCAHS to operate the Statewide Agriculture and Farmworker Education (SAFE) program. WCAHS works with both agriculture industry groups and worker advocacy organizations to engage front-line supervisors and workers directly in the fields, conducting trainings on legal obligations and protections for agricultural workers. LWDA has worked with CDFA to inform agricultural employers of the availability of this program, expanding the number of employers that are inviting the SAFE program to train their staff.

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.[129]

LWDA oversees the Rural Strategic Engagement Program (RSEP), an effort reduce the obstacles that farmworkers have to accessing state services. One of the strategies of this program has been to launch in-person clinics in rural areas of the State in collaboration with local farm-working serving organizations. Staff from the California Department of Industrial Relations' (DIR) Division of Occupational Safety and Health Cal/OSHA, the Labor Commissioner's Office, the Employment Development Department, and Agricultural Labor Relations Board, are present at these regularly (either monthly or quarterly) scheduled clinics to distribute information, educate workers, and assist workers with filing claims or complaints. Additionally, the clinics receive funding to provide legal services to farmworkers considering filing a claim for a potential violation.

Cal/OSHA is California's leading agency on mitigating the occupational risks, including climate-driven risks, through regulatory enforcement, programs, research and outreach initiatives. DIR 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.

DIR's Worker Occupational Health and Safety 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. 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. Unsafe working conditions can be reported directly to Cal/OSHA by phone, through their website, or at a local Cal/OSHA office.

DIR's California Workplace Outreach Program (CWOP), in its fifth iteration, currently funds 90 organizations throughout the State to conduct direct outreach to workers. DIR works with these organizations to educate workers about the services and protections offered by its divisions, including the Labor Commissioner's Office and Cal/OSHA. Agriculture is a priority industry for this program, and protections against extreme heat is a priority topic for outreach. Around a third of the organizations participating in this program are focused on rural areas of the state. Outreach goals for this program prioritize distribution of physical assets to workers and in-depth engagement with workers to address questions and inform them of their options if there are existing violations.

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.

Chapter 3: Support Agricultural Workforce Wellbeing and Health

Cal/OSHA Consultation Services Branch also helps reduce occupational risks and health hazards by providing on-site consultation to employers that involves a review of safety plans, plan implementation, and any previous injuries, identification of potential hazards at the worksite, and provides information for fixes to improve the health and safety of the worksite.

The California Department of Public Health also provides key resources for occupational health and heat hazards at work. This includes the Worker Heat Effects and Tracking (HEAT) program which provides prevention and education resources to employers and workers in high-risk occupational settings. The program's multidisciplinary team conducts research on heat-related illness in California, works with partners to train workers and employers, and facilitates collaboration.

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.

Extreme Heat Challenges

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, now maintained by California Department of Public Health’s (CDPH) Office of Health Equity’s Climate and Health team, 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 8 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.

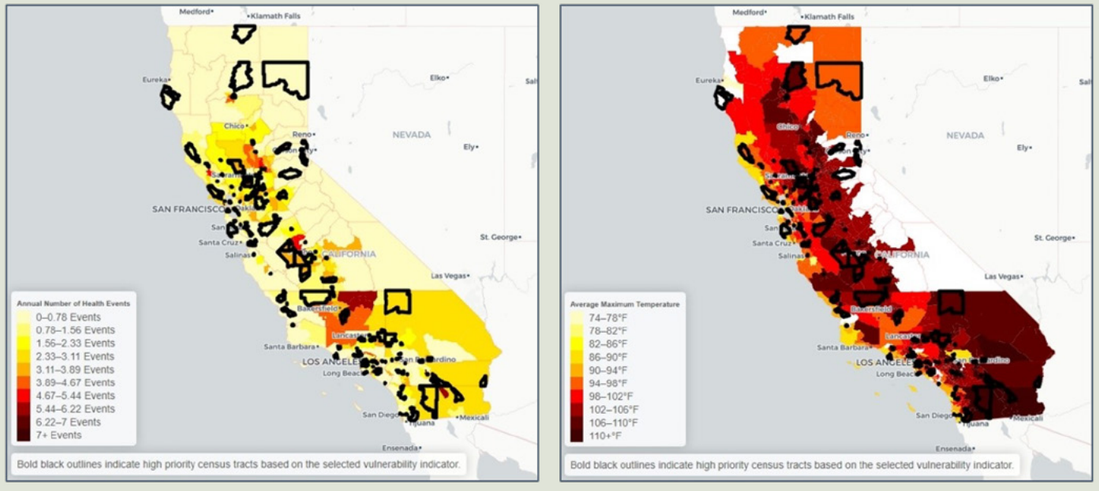


Figure 8: California Heat Assessment Tool

Extreme Heat Challenges

In 2025, California launched CalHeatScore, the state’s extreme heat early warning system.[130] CalHeatScore was created to protect all Californians from extreme heat, especially those most vulnerable like outdoor workers. Like other 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 9 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 community’s vulnerability to heat, including the percentage of the population in that works outdoors.

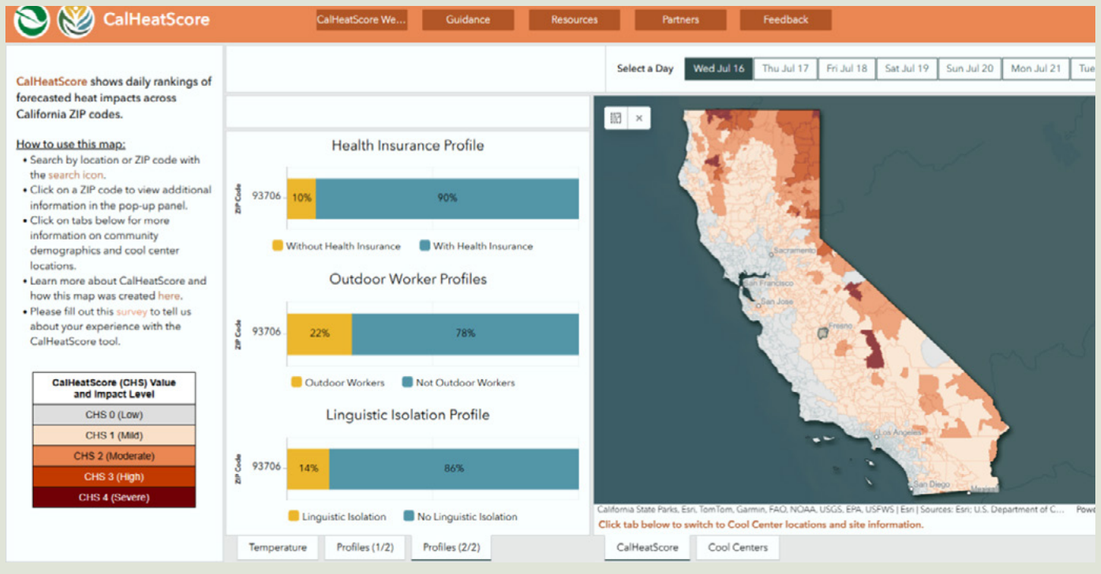


Figure 9: CalHeatScore Platform

3.1.3 Support programs that provide mental health resources and training for all people working on farms.

Goal 4: Provide Health and Environmental Benefits

Climate change is among a list of factors impacting the mental health of farmers and farmworkers globally.[131] CDFA maintains a webpage that lists resources for farmer and farmworker mental health. This work is supported by the USDA National Institute of Food and Agriculture, which lists a number of hotlines for mental health emergencies, disaster assistance resources, and tips for dealing with stress.

Stakeholder Feedback

Stakeholders would like to see expanded TA training to cover challenges such as mental health.

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

Goal 4: Provide Health and Environmental Benefits

Community Resilience and Planning

California has passed several laws that remove barriers to construction for various types of housing, including farmworker housing. This includes the Employee Housing Act which created three ways to streamline zoning for agricultural employee housing (HSC 17021.5; HSC 17021.6; HSC 17021.8). The Housing Accountability Act sets a higher bar for a local government to deny certain affordable housing projects, including farmworker housing (GC 65589.5). The Permit Streamlining Act sets a time limit for local jurisdictions to review an application for housing development projects, including farmworker housing, and also allows an applicant to submit a preliminary application which confers benefits under the Housing Accountability Act (GC 65943; GC 65941.1) For qualifying farmworker housing projects, the benefits and protections of the State Density Bonus Law can apply. This Law incentivizes the construction of affordable housing by allowing a developer to add more housing units to a project beyond the zoned capacity and secure other "incentives" in exchange for a commitment from the developer to include deed-restricted affordable units in the project (GC 65915). The Housing Element law indicates that the housing element in cities' and counties' general plans include specific provisions for special needs households, including farmworkers and extremely low-income households. These provisions include analysis of housing needs and then these needs are addressed through program commitments with specific timelines that are geared toward housing outcomes for farmworkers (GC 65583).

In addition, there are multiple programs at the state which provide collaboration and guidance opportunities focused on land use and community development, climate risk and resilience, and high road economic development. Agriculture specific topics include:

- The Governor's Office of Land Use and Climate Innovation's (LCI) Integrated Climate Adaptation and Resiliency Program (ICARP)'s 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.
- ICARP's Vulnerable Communities Platform is a tool in development to identify statewide those people 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 CDPH Community Health Workers, Healthy Homes, and Healthy Families weatherization pilot project works to implement weatherization and energy efficiency improvements as protective health interventions for low-income families and farmworker communities in Tulare County, California.
- 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.
- HCD's Prohousing Designation Program (PDP) seeks to acknowledge and support jurisdictions that go above and beyond state housing law to accelerate housing production. A jurisdiction with a Prohousing Designation may receive priority processing or funding points when applying for several state funding programs and allows jurisdictions to apply to the Prohousing Incentive Program (PIP). PIP is designed to reward local governments with additional funding to accelerate affordable housing production and preservation. Local governments can receive points in the Prohousing Designation application for removing barriers to farmworker housing.
- Pursuant to Assembly Bill 1654 (Rivas, 2022), HCD has been conducting a Farmworker Housing Study since 2023 to further understand farmworker housing needs statewide. The study includes the following goals:
  - Analyze farmworker demographics, wages, and existing housing studies at the state, regional, and county levels.
  - Identify barriers and opportunities to farmworker housing development through listening sessions, interviews, and/or focus groups.
  - Produce quantitative estimates of farmworker housing needs at different income levels using existing data.

Stakeholder Feedback

Stakeholders want to see expanded interdepartmental collaborations between CDFA, the Business, Consumer Services, and Housing Agency, and the Labor and Workforce Development Agency to continue to address infrastructure, health, and safety challenges for the agricultural workforce.

- The California Department of Community Services and Development administers the Low-Income Weatherization Program's (LIWP) Farmworker Housing Component. Serving counties that have the highest farmworker populations, the program focuses on the direct installation of energy efficiency measures and solar photovoltaic (PV) systems to low-income farmworker households at no cost. This lowers emissions, reduces energy costs, and facilitates health and safety improvements for residents.
- 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.[132] 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.

In addition, the Strategic Growth Council's Community Resilience Centers funds the planning, construction and retrofitting of community resilience centers across California to bolster capacity to respond to and recover from emergencies. The program has awarded $5,285,338 for 11 Planning Grant projects, $8,985,850 for four Project Development Grant projects, and $83,250,226 for nine Project Implementation Grant projects in 2024. A second round of awards are anticipated with $55 million allocated for the program in the 2024 Climate Bond.

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.[133]

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 adaptations in California agriculture, and detail on the impacts of atmospheric rivers on water infrastructure.[134]

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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.	4: Provide Health and Environmental Benefits	Cal/OSHA	California Code of Regulations Section 3395, Extreme Heat Action Plan, SB 1105 (Padilla, 2024)
3.1.2 Support research and collaboration into on-farm tools for health and safety.	4: Provide Health and Environmental Benefits	DIR, Cal/OSHA, EDD	UC Davis Center for Farm Health and Safety, Climate Action Seed Grants, Worker Occupational Health and Safety Training and Education Program (WOSHTEP), Migrant and Seasonal Farmworker Outreach Program, California Heat Assessment Tool, CalHeatScore, California Heat Illness Prevention Research, Wildfire Smoke Map, DIR Heat Illness Prevention Guidance, Heat Effects and Tracking (HEAT) Program
3.1.3 Support programs that give resources and training for all people working on farms for mental health.	4: Provide Health and Environmental Benefits	CDFA	Farmer & Farmworker Mental Health Resource Page
3.1.4 Implement programs that build and improve infrastructure in rural agricultural communities to better support resilience to extreme weather events.	4: Provide Health and Environmental Benefits	CDFA, LCI, HCD, DCSD	Conservation Agriculture Planning Grant Program, Integrated Climate Adaptation and Resiliency Program (ICARP), Extreme Heat and Community Resilience Program, Vulnerable Communities Program, Joe Serna Jr. Farmworker Housing Grant Program, Adaptation Planning Grant Program, Regional Resilience Planning and Implementation Grant Program, Farmworker Resource Center Grant Program, Fairground and Community Resilience Centers Programs

4 Protect Animal Health

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

California's livestock sector is a major contributor to the state's agricultural economy, but it is increasingly affected by climate change. Rising temperatures and more frequent extreme heat events pose serious risks to animal welfare, leading to reduced feed intake, lower reproduction and milk production, greater disease susceptibility, and—in severe cases—large-scale livestock mortality. Climate change also affects the quantity and nutritional quality of animal feed and water by reducing forage productivity and increasing water stress, particularly in already arid regions. In addition, warmer temperatures and shifting precipitation patterns are accelerating the spread of pests and infectious diseases, creating significant biosecurity and food system risks. Together, these impacts threaten animal health, food safety, and the long-term productivity and resilience of California's livestock industry.

This chapter highlights how California is enhancing protections for livestock and animal health through expanded technical assistance, disease prevention programs, research, and predictive tools, while coordinated emergency preparedness, disease traceability, and infrastructure investments support food safety, animal welfare, and industry resilience.

Context

California's livestock commodities represent a significant proportion of the state's agricultural value.

In 2024, Dairy Products/Milk and Cattle and Calves were the first and fourth ranked commodities in the state, bringing in over $13.5 billion in market value.[135] Climate change brings many challenges to livestock production, threatening the health of animals, food safety and security, and commodity production. Climate change-driven factors such as rising temperatures, more frequent extreme heat events, and the spread of pests and diseases pose significant challenges to livestock production, as shown in Figure 10. These stressors can lead to reduced productivity and increased livestock mortality.

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.[136] Since 1985, average annual air temperatures in the state have increased by about 2.5° F.[137] By 2050, the daily maximum average temperature is

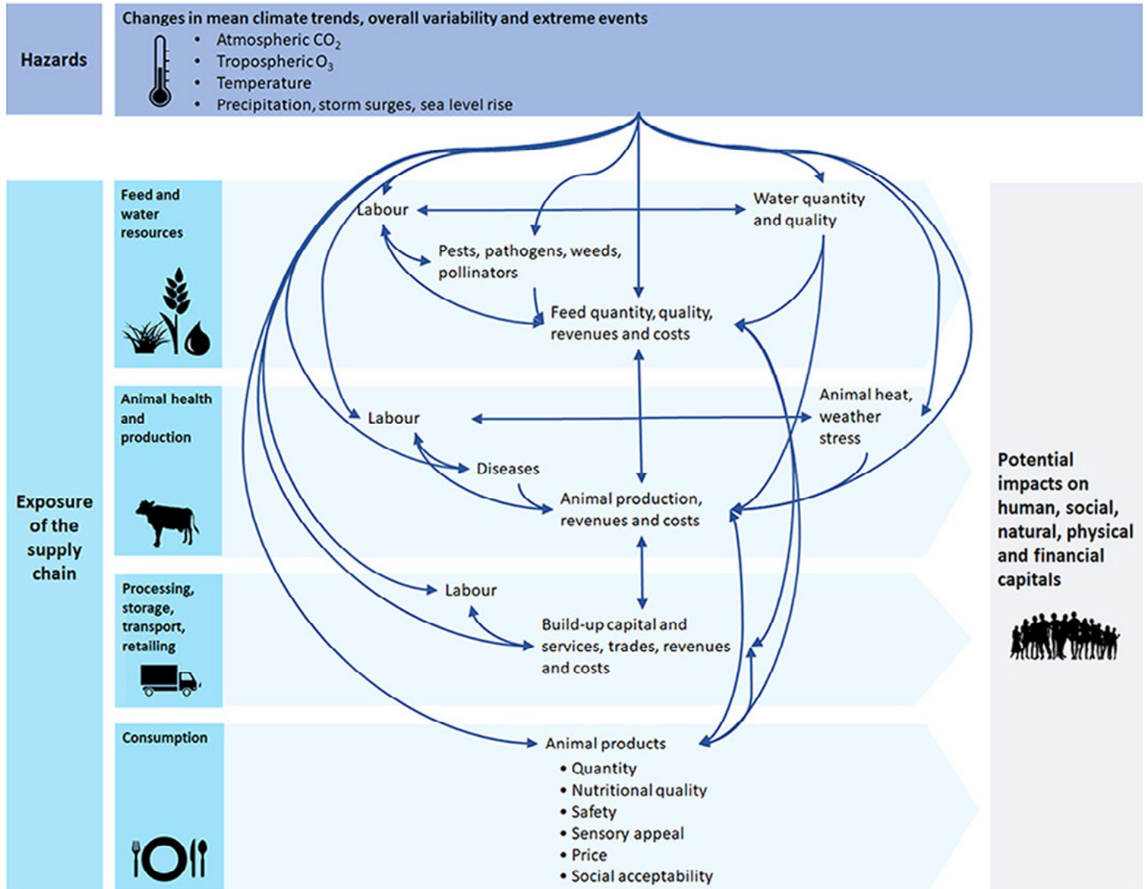


Figure 10: Impacts of Climate Change on Livestock Food Supply Chain

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.[138] Extreme heat events, when temperatures are at or above the highest 5 percent of historical values, are also increasing.[139] 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.[140] High heat conditions also disrupt reproduction and decrease milk production for dairy cows.[141] 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 feed 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.[142] Water-stressed regions may become more water limited, leading to lower forage productivity for grazing livestock.[143] Heat stress and water limitations can also decrease the nutrient content of animal feed.

Disease and Pest Pressures

Rising temperatures can increase the growth and survival rate for pathogens, transmission rates, and host susceptibility.[144] 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.[145] 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.[146] 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.[147] 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).[148]

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.[149]

Strategies 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 responses to threats to 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 to animal health with ongoing technical assistance.

Goal 4: Provide Health and Environmental Benefits

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 4: Provide Health and Environmental Benefits

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.[150]

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.

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

Goal 4: Provide Health and Environmental Benefits

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 as follows.

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.

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.

Chapter 4: Protect Animal Health

The C.A.T.T.L.E. Act (Caring About the Terrain, Livestock, and Ecosystems Act)

In 2025 the California legislature enacted AB 411 (Papan, 2025), known as the C.A.T.T.L.E. Act (Caring About the Terrain, Livestock, and Ecosystems Act), authorizes the on-farm composting of livestock carcasses in California under specified conditions. Historically, state regulations largely prohibited the composting of unprocessed mammalian tissue, limiting disposal options for livestock producers and often requiring costly or logistically challenging alternatives such as rendering or off-site disposal. AB 411 responds to these challenges by allowing producers to compost livestock carcasses resulting from routine mortality or on-farm processing, provided they follow best management practices adopted by the California Department of Food and Agriculture. These practices are intended to protect public health, soil and water quality, and biosecurity while minimizing odors and pests. The law aims to provide an environmentally sound, practical disposal option, support nutrient recycling back into agricultural soils, and align California with composting practices already permitted in many other states.

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 packing 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.

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
4.1 Establish and support proactive responses to threats to animal health.			
4.1.1 Be proactive to threats to animal health with ongoing technical assistance.	4: Provide Health and Environmental Benefits	USDA, CDFA	Wildlife Services Program, California Avian Health Education Network
4.1.2 Support research and predictive tool development.	4: Provide Health and Environmental Benefits	CDFA, OES	California Veterinary Emergency Team, Animals in Disasters Working Group, USDA Agricultural Research Service
4.1.3 Prepare for emergency situations with state agency coordinated procedures and infrastructure.	4: Provide Health and Environmental Benefits	CDFA, USDA	Animal Traceability Framework, Mandated Ear Tags for Cattle and Bison, California Animal Response Emergency System (CARES), Meat Poultry and Egg Safety (MPES) Program, California Secure Food Supply (SFS), AB 411 C.A.T.T.L.E. Act

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.

Energy is an essential input to the agricultural system, powering on-farm equipment like pumps and tractors to processing facilities and refrigerated transport. Historically, much of this energy has been generated with fossil fuels, contributing significantly to greenhouse gas emissions. California has been actively working to build a resilient, decarbonized energy system by expanding renewable energy capacity and setting ambitious goals, such as electrifying 25 percent of the agriculture industry by 2030 and 75 percent by 2045, alongside achieving 100 percent renewable retail electricity by 2045. Multiple state and federal agencies collaborate to support programs that improve energy efficiency and promote electrification in agriculture, focusing on both behavioral changes and technological advancements. Key areas of focus include improving pumping and irrigation efficiency, the primary use of on-farm energy, as well as research into innovative technologies that convert agricultural byproducts into new and efficient energy resources. Achieving California's climate and agricultural goals requires a holistic approach to energy planning that ensures reliable, affordable, and clean power to sustain the agricultural economy.

This chapter discusses how the state aims to support the agricultural sector's transition to electrification and greater energy efficiency by addressing barriers through regional energy demand assessments, multi-agency collaboration, and targeted programs that incentivize behavioral changes and technological upgrades, all while maintaining California's high agriculture productivity.

Context

Energy is a critical input to every part of the food supply chain.

On farms, access to reliable energy is essential for everything from water conveyance to traditional on-farm equipment—such as pumps, tractors, and harvesters—as well as newer technologies like seeding drones, soil-moisture monitors, and weeding robots. Further down the supply chain, energy remains critical in food-processing facilities for cleaning and packaging products, and for the refrigerated trucks that deliver them to neighborhood grocery stores. Historically, this fleet of equipment has largely been powered by fossil fuels and is a significant source of GHG emissions.[151] In recent years, wildfire weather conditions and extreme weather events have resulted in strains on the electrical grid and highlight the importance of energy efficiency and reliable sources of energy to maintain highly productive 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 diversification of 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 for Achieving Carbon Neutrality (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 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 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.[152] 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 implementation planning 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.

Stakeholder Feedback

Stakeholders strongly support on-farm energy pathways, including solar installation and biomass to energy, that provide renewable energy and improved bottom lines.

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 3: Support Economic Development

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 energization 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 (IEPR).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.[153] 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 IEPRs. 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).[154] Funded through the California Jobs First Initiative, this effort provides a holistic planning and implementation project to provide high quality, climate resilient, 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.

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. Support energy efficiency projects that reduce energy consumption while maintaining high productivity in the food system, both on and off-farm.

Stakeholder Feedback

Stakeholders urge caution in energy efficiency actions such that they do not hinder agricultural production and encourage investment in research and outreach through the state's university system.

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

Goal 2: Reduce Greenhouse Gas Emissions

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 electricity consumption. These changes can result in shifting electricity usage from peak 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.[155] 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.[156] This highlights the importance of these programs as well as the infrastructure which allows for the implementation of these price programs, such as individual customer meter upgrades.

However, careful consideration to operational needs and feasibility of usage shifts should be made prior to considering an alternative rate option. In the past, the CPUC has authorized IOUs to offer bill protection to customers who switch to

new rate plans thereby minimizing the financial risk during this transition period. Bill protection ensures a customer is made whole if their new rate structure ends up being more costly than their previous one.

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 discounted pricing 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.[157] 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, which allows customers to install self-generation electricity systems while staying connected to the grid 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 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: Reduce Greenhouse Gas Emissions

Infrastructure, 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. These programs are increasingly important as the targets from the 2022 Scoping Plan draw nearer, i.e., electrifying 25 percent of the agriculture industry by 2030 and 75 percent by 2045. 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. The CORE program funds the purchase or lease commercially available zero-emission off-road equipment. Agricultural equipment is eligible for up to $500,000 in incentives, and up to $30,000 for infrastructure enhancements. This program has been oversubscribed every year of its existence and highlights the importance of program expansion for reaching the state's climate and air quality goals. 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.

In 2023, the CPUC expanded the terms of its "on-bill financing" programs, administered by the IOUs, aimed at assisting non-residential customers in making comprehensive energy investments to include clean energy technologies, such as battery storage, electric vehicle

charging infrastructure, and solar generation for non-residential utility customers.[159] This is in addition to the existing energy efficiency types of investments already eligible such as exterior and interior LED lighting, heating, ventilation and air conditioning (HVAC), electric motors, refrigeration, food service equipment and water pumps. On-bill financing programs offered by IOUs allow for zero percent financing for loans between $5,000 and $400,000 with exceptions made up to $6 million for individual premises. On-bill financing programs place the loan repayment amount on the customers bill for a duration of up to 120 months with no pre-payment penalties. These special financing offers can help operators with needed facility upgrades, fund agrivoltaic projects, or invest in battery storage for farm equipment purposes.

Through Proposition 4 (2024), CDFA received $15 million for a new Equipment Sharing Program (ESP), which will require extensive stakeholder consultation prior to opening in late 2026. This grant program would help facilitate equipment sharing across various agricultural regions throughout California. Equipment funded through this program could utilize the latest energy efficient technology to further support farmers with reduced energy costs. Examples of equipment that may prove useful include no-till drills, manure/compost spreaders, off-ground harvesters, orchard chippers, and solar-powered cold storage trailers. Preference will be given to projects and programs that benefit small- and medium-sized farms and socially disadvantaged farmers and ranchers. CDFA is currently in the process of developing this grant program.

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.[158] 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.

Chapter 5: Advance Energy Efficiency and Decarbonization for Agricultural Operations

Water & Energy Use Efficiency

Pumping water from underground aquifers and moving water from one location to another, such as through 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.[160] 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.[161] In addition, there are embedded energy savings in water-use efficiency overall, because using less water reduces the energy required for pumping, conveyance, storage, treatment, delivery, maintenance, and heating for end use.

During a drought year, the use of groundwater increases to make up for the shortfall in surface water which is due to less 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 aquifer.

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 2021, the CPUC approved the electric investor-owned utilities' EV Infrastructure Rules, which are designed to accelerate EV charging deployment by covering utility-side of the meter infrastructure to support customers installing separately metered EV charging infrastructure. 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.[162] Additionally, on December 18, 2025, the CPUC adopted two resolutions, Pending Loads and Scenario Planning, which aim to enable the IOUs to become more flexible in meeting anticipated load growth from customer electrification requests through proactive planning efforts.[163]

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

Stakeholder Feedback

Stakeholders suggest creating incentive programs for agrivoltaics, including funding grants to support pilot projects, demonstration sites, and research.

What are agrivoltaics?

While not defined in California code, the concept of "agrivoltaics," or solar voltaic systems run in combination with agricultural production, has been gaining steam. Elsewhere in the world, with Europe and Asia leading the way, agrivoltaics are used to provide 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 provides the opportunity for energy generation without displacing farmland (for more information on agrivoltaics and land use, see Chapter 6). 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 aims at solving a common problem associated with agrivoltaics, the shading out of crops. However, the shading provided by solar PV panels is not necessarily a strict drawback; studies have shown that the dual-purpose goals of agrivoltaics in the right environment and with the right crops, can improve crop production, decrease irrigation requirements, improve solar production from cooler panels, and provide necessary refuge from the sun and heat for livestock.[165]

Additional pilot agrivoltaic systems are installed at UC Merced, CSU Fresno, and CalPoly Pomona. These projects will help researchers collect real farm data focusing on outcomes such as crop quality, water savings, electrical value, and the use of smart shade controls that can be used to accommodate crop needs and weather conditions.

In August 2024, CEC released an EPIC funded grant funding opportunity, GFO-24-301159 Environmental Sustainability of a Clean Energy Transition (Enviro-SET)160 that will provide up to $700,000 to fund 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. Agrivoltaics also have the benefit of providing shade and shelter for livestock animals and could be used in a ranching context as well.[166]

Chapter 5: Advance Energy Efficiency and Decarbonization for Agricultural Operations

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 and vineyard crops, requires regular pruning of tree limbs and vines. Orchards also have limited lifespans and must periodically be replaced. These activities create woody biomass, traditionally considered waste, which then must be disposed of. Historically, these materials were burned in the field, but as the state has worked to improve air quality, burning of agricultural waste is being phased out. Additionally, increased efforts around forest management mean that there is likely to be a steady supply of woody biomass into the future. It is estimated that California produces approximately 29 million bone dry tons of woody biomass annually from forests, farms, and orchards.[167] However, there are emerging opportunities to use excess woody biomass as a feedstock for the production of fuels such as hydrogen, as well as low-carbon intensity ammonia for fertilizer.

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.[168]

CDFA's Dairy Digester 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.

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 partially funded other fully operational dairy digester projects which sell power to electric utility customers through the CPUC's Bioenergy Feed-in Tariff Program, the Bioenergy Market Adjusting Tariff (BioMAT) program.[169] 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 has a high carbon intensity (CI), whereas hydrogen produced from dairy biogas has a comparatively lower carbon intensity.

Hydrogen produced on farms can reduce carbon emissions through several applications, including as a fuel for vehicles and equipment, and an input for making ammonia fertilizer. Hydrogen can be used in fuel cells or in a modified 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 biogas, renewable energy, or biomass can also be used to produce low CI ammonia for fertilizer; this pathway for fertilizer decreases transportation of fertilizers as well.[170]

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.[171] 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: CO_2 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.

Sustainable Aviation Fuel

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.

Case Study: Efficient Energy Improves Fresh Food Access and Powers Local Communities

Project Funding Program: Healthy Refrigeration Grant Program

Awarded Business: Rancho Market and Produce

Award Year: 2024

Market Location County: Alameda

Access to fresh and nutritious food is affected by several factors like climate change and its disruption of supply chains, as well as historical and socioeconomic factors like redlining and poverty. Several reports have found that despite California producing over a third of the country's vegetables and over three-quarters of the country's fruits and nuts, 20 percent of Californians do not have reliable access to fresh produce. The lack of fresh produce in diets contributes to chronic diet-related diseases that disproportionately affect low-income communities and communities of color.

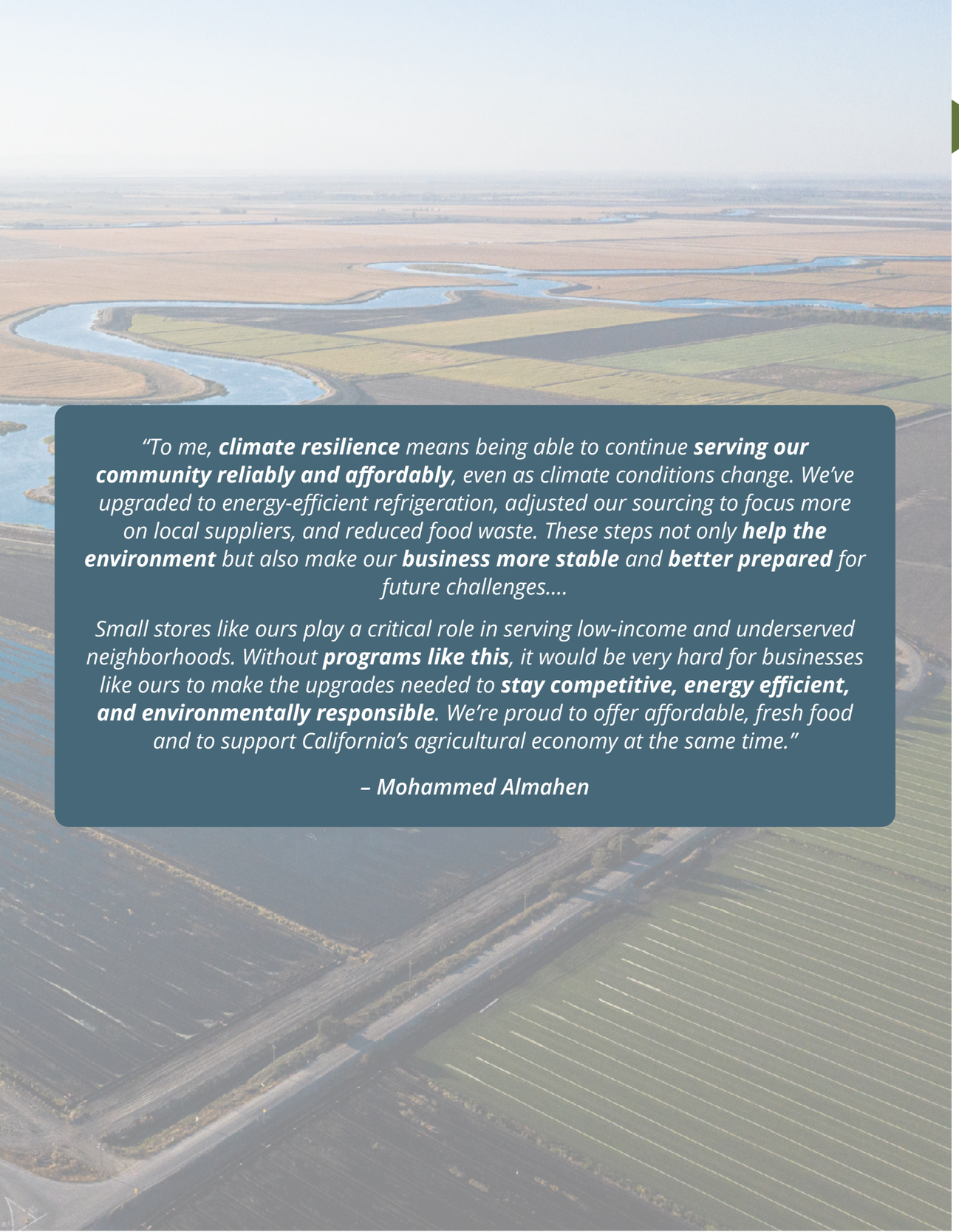
Mohammed Almahen is the manager a family-owned grocery store Rancho Market and Produce in Alameda County that has aimed to fill food access gaps for their community for over 25 years. Understanding the importance of providing safe, fresh, and culturally relevant foods to the community he serves, Almahen applied to the **Healthy Refrigeration Grant Program** through CDFA to invest in his store's hardware and more efficiently serve his customer base.

The upgrades to their refrigeration systems allowed their operation to weather supply chain disruptions for whole foods driven by climate change (e.g., more frequent heatwaves, noticeably reduce their food waste, and increase their energy and cost efficiencies.

Mohammed also found that the hardware upgrade allowed him to stock a wider variety of fresh produce than what his customers can usually access in the community.

Mohammed Almahen of Rancho Market and Produce.

Fresh produce displayed at Rancho Market in Healthy Refrigeration Program-funded refrigerators.



*"To me, **climate resilience** means being able to continue **serving our community reliably and affordably**, even as climate conditions change. We've upgraded to energy-efficient refrigeration, adjusted our sourcing to focus more on local suppliers, and reduced food waste. These steps not only **help the environment** but also make our **business more stable** and **better prepared** for future challenges....*

*Small stores like ours play a critical role in serving low-income and underserved neighborhoods. Without **programs like this**, it would be very hard for businesses like ours to make the upgrades needed to **stay competitive, energy efficient, and environmentally responsible**. We're proud to offer affordable, fresh food and to support California's agricultural economy at the same time."*

– Mohammed Almahen

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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.	3: Support Economic Development	CEC, CPUC, CARB	Integrated Energy Policy Report, California Jobs First Initative - Sierra San Joaquin Jobs (S2J2)
5.2. Support energy efficiency projects that reduce energy consumption while maintaining high productivity in the food system, both on and off-farm.			
5.2.1 Support demand flexibility and improve energy efficiency through incentivized behavior changes.	2: Reduce Greenhouse Gas Emissions	CPUC, CEC	Time-of-Use Pricing, PG&E Peak Day Pricing (PDP), Demand Response Programs, Net Billing Tariff, Dynamic Pricing for Agriculture, Joint Agency Reliability Planning Assessment Report
5.2.2 Improve energy efficiency and flexible electricity demand through technological upgrades.	2: Reduce Greenhouse Gas Emissions	CARB, CEC, CDFA	Clean Off-Road Equipment (CORE), Carl Moyer Air Quality Standards Attainment Program, Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program, REDWDS grant funding, REDWDS' Electric Farm Vehicles as Reliable Grid Assets, Electric Program Investment Charge (EPIC), Food Production Investment Program (FPIP), Environmental Quality Incentives Program (EQIP) On-Farm Energy Initiative, Agriculture Energy Savings Action Plan, State Water Efficiency and Enhancement Program (SWEEP), Dairy Digestor Research & Development Program (DDRDP), Biomethane Monetary Incentive Program, Emerging Technology Program (ETP)

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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.

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.

California's agricultural lands are uniquely productive, supplying a large share of the nation's most nutritious foods, including half of its vegetables, three-quarters of fruits and nuts, and one-fifth of milk. However, this critical land base is increasingly threatened by farmland conversion and water scarcity-driven fallowing. California ranks among the top states for agricultural land loss, with more than 1.6 million acres converted to non-agricultural uses since 1984, often on the state's most productive soils. At the same time, implementation of the Sustainable Groundwater Management Act (SGMA) is expected to drive water-use changes which could result in grower decisions to retire an estimated 500,000 to 1,000,000 acres of farmland as groundwater pumping is reduced to stabilize depleted aquifers, potentially leading to unmanaged fallow lands, declining land values, and disproportionate impacts on underserved farmers and farmworker communities. While groundwater sustainability is vital for long-term water security, the loss or fragmentation of farmland threatens food production, environmental quality, and rural economies. Protecting and strategically managing California's agricultural land base is therefore essential to maintaining a resilient food system and supporting a diverse, nutritious food supply.

This chapter explores how the state can implement policies and initiatives to support the protection and conservation of agricultural lands, as well as facilitate informed land use decisions that support resilient agricultural systems.

Context

California's lands produce the bulk of the most nutritious foods grown in the United States, including half of all vegetables, three-quarters 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.[1]

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.[2] 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.[3] 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.[4] Once productive farmland is transitioned to other uses, it can't be easily brought back into 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.

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.

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 (SGMA), which directs local Groundwater Sustainability Agencies (GSAs) to develop and implement plans to achieve sustainable groundwater management and avoid undesirable results. 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 declining water levels.

SGMA is likely to be a major driver of water-use change, which could mean changes in irrigation practices, changes in the types of crops grown, or changes in land use. 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 results 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 is determined by land owner/operators in response to GSA set groundwater management decisions such as pumping limits, allocation rules, or sustainable yield targets. However, there is a risk that if land transition doesn't happen in a coordinated, orderly way, it could lead to an uncoordinated "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.

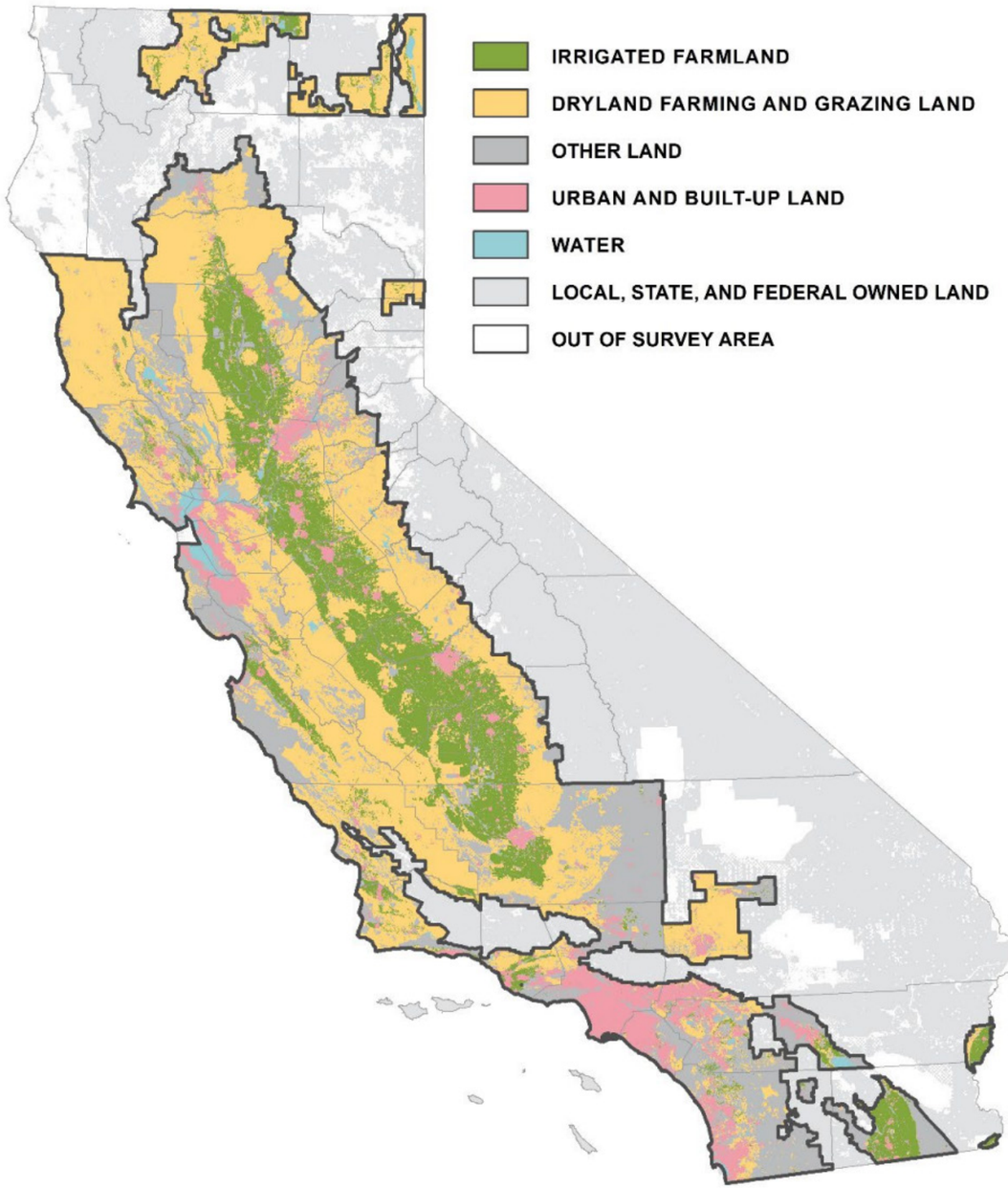

Figure 11: California Farmland Conversion Report

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 they 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

Stakeholder Feedback

Stakeholders felt that the Williamson Act remains a critical tool for preserving agricultural and open-space lands through voluntary contracts between landowners and local governments. They recommend restoring county subvention funds as this would strengthen voluntary farmland conservation, uphold market-based land access to farmland, and reduce pressure for land conversion.

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 4: Provide Health and Environmental Benefits

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.

Stakeholder Feedback

Stakeholders recommend the state conduct an analysis of how much progress can be made based on current investment in SALC, and how much progress would be made toward the conservation goals set by AB 1757.

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

Goal 4: Provide Health and Environmental Benefits

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.

Stakeholder Feedback

Stakeholders recommend the SALC program create a resource hub for planning grant recipients including policies, funding sources, and technical assistance tools that are available to fund projects, goals, and objectives outlined within SALC planning grants.

Stakeholders suggest local governments adopt in-lieu mitigation fees to mitigate for agricultural land lost to development.

Santa Clara Valley Agricultural Plan

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. Development of the plan was funded by the Sustainable Agricultural Lands Conservation Program.

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

Goal 4: Provide Health and Environmental Benefits

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 all 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.

Stakeholder Feedback

Stakeholders recommend integrating management strategies for climate mitigation and resilience into the General Plan Guidelines.

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 to ensure that all languages and 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 4: Provide Health and Environmental Benefits

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 3: Support Economic Development

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 brought 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.[5]

The state's primary electricity planning process–the CPUC's Integrated Resource Planning (IRP)–both identifies the mix of resource attributes needed to reliably serve state electric load and meet state climate goals. Through a part of 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.[6] 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.

Stakeholder Feedback

Stakeholders would like to see the state track existing agrivoltaics projects to better understand where and to what extent these dual land uses are occurring in the state.

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

Goal 4: Provide Health and Environmental Benefits

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 (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 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. MLRP releases an annual report to ensure transparency and accountability, and receives input from an interagency advisory committee. An additional $200 million of Prop 4 dollars will be allocated to MLRP.

Stakeholder Feedback

Stakeholders recommend that the state assess the impact of development pressures including those from data centers, renewable energy, and other emerging threats on agricultural communities by drafting a report that examines effects on land prices, water access, and communities.

Stakeholders also recommend that the state conduct an analysis of needs related to the anticipated retirement of farmland in addressing environmental and economic impacts.

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 (though stakeholders note that reducing food waste would also contribute to meeting this demand). In California in 2022, the average age of a farmer was 59.9. 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 1: Improve the Bottom Line for Farmers

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.[7] Women and minority producers represent 37 percent and 9 percent of all farmers in the state, respectively.[8] As noted in the Farmer Equity Act of 2017, these 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.[9] From 2017 to 2022, the number of small farms in California decreased disproportionately. 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.[10] This shift in land use patterns may have broader social and environmental impacts, such as reduced agrobiodiversity, fewer rural jobs, and decreased rural community vitality.

Stakeholder Feedback

Stakeholders recommend the state conduct an analysis of the financialization and consolidation of farmland, as well as the land management implications of these different ownership types and their impact on state climate goals.

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 increased acquisition of farmland by private equity firms, hedge funds, and venture capital firms, has made it difficult for new farmers to afford land. Stakeholders identified the need to address the affordability of farmland as a high priority.

Additionally, as discussed before, 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 factors such as water scarcity, 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 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 more difficult for tenants to access incentive funding through programs that have ownership or long-term lease requirements (see Appendix A for a list of equity considerations for inclusive program design).

Stakeholder Feedback

Stakeholders recommend the state create a Buy-Protect-Sell revolving loan fund that incorporates affordability mechanisms such as the Option to Purchase at Agricultural Value and the Right of First Refusal.

Stakeholders also called for limiting pension and investment fund ownership of agricultural land.

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.

The SALC Round 10 guidelines stipulate that 20 percent of funds be allocated to projects that support secure and tenure or provide meaningful benefits to priority populations. Prop 4 includes $30 million allocation to support land access and tenure for socially disadvantaged farmers or ranchers, tribal producers, and beginning farmers and ranchers.

One model used by many land trusts is the "buy-protect-sell" model, a specific type of agricultural easement transaction wherein an easement is placed on land that is owned or will be purchased by an eligible entity (usually a land trust) and then the land is transferred to a qualified farmer or rancher. Buy-protect-sell transactions are eligible through SALC and CFCP, as well as the USDA NRCS' Agricultural Conservation Easement Program-Agricultural Land Easements (ACEP-ALE).

Stakeholder Feedback

Stakeholders recommend that the state adopt an "Option to Purchase at Agricultural Value" (OPAV) program. OPAV programs are adopted statewide and require that when conservation easement-encumbered land is sold, it is sold at a price that reflects its agricultural value rather than a non-farming market demand, such as rural estates. Vermont and Massachusetts adopted OPAV programs to address the rising cost of farmland and ensure that protected farmland remains available for commercial agriculture. Another mechanism stakeholders suggested is a tool called Right of First Refusal, which allows a designated individual–such as a farming heir or co-owner–the opportunity to buy a piece of property if the current owner decides to sell.

Stakeholder Feedback

Stakeholders recommend a series of actions to address the long-term affordable access to farmland:

- Establish an Ancestral Land Return Fund;
- Return publicly held land to California Native American Tribes;
- Establish a Restorative Land Fund;
- Establish down payment, loan and debt forgiveness programs;
- Expand tailored technical assistance for land access and acquisition;
- Limit pension and investment fund ownership of agricultural land;
- Improve conservation programs and tools to enable equitable land access and stewardship;
- Promote local strategies for agricultural land preservation;
- Provide beginning farmer tax credits (e.g., Ohio).

Others requested the state ensure that all efforts aimed at expanding access ensure that land transfers are strictly voluntary, free from any use of coercion or eminent domain powers, and are based on the fair-market value of agricultural lands.

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

Goal 1: Improve the Bottom Line for Farmers

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.[11] 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.

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.[12] 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.

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
6.1 Implement policies and initiatives to support the protection and conservation of agricultural lands.			
6.1.1 Permanently protect strategic agricultural lands.	4: Provide Health and Environmental Benefits	DOC, SGC,	California Farmland Conservancy Program (CFCP), Sustainable Agricultural Lands Conservation Program (SALC)
6.1.2 Build local government capacity to identify and protect agricultural lands.	4: Provide Health and Environmental Benefits	DOC, SGC, LCI	Santa Clara Valley Agriculture Plan
6.1.3 Update General Plan guidelines to better address and prevent farmland loss.	4: Provide Health and Environmental Benefits	LCI	Office of Land Use and Climate Innovation Guidelines
6.2 Facilitate informed land use decisions that support resilient agricultural systems.			
6.2.1 Enable community decision-making using land-use mapping tools.	4: Provide Health and Environmental Benefits	DOC, GoBiz	DOC GIS Mapping Tools, Sierra San Joaquin Jobs Initiative, CA Jobs First
6.2.2 Track existing processes that identify resource needs to support state climate goals.	3: Support Economic Development	CEC	Integrated Resource Planning Process, Cropland Index Model
6.2.3 Where land conversion occurs, enable orderly, equitable, community-driven land use decisions.	4: Provide Health and Environmental Benefits	DOC	Multibenefit Land Repurposing Program (MLRP)
6.3 Facilitate equitable land access to promote local food production and economic growth.			
6.3.1 Address challenges with agricultural land access.	1: Improve the Bottom Line for Farmers	SGC	Healthy Soils Program
6.3.2 Provide an in-road to agriculture for the state's urban residents.	1: Improve the Bottom Line for Farmers	CDFA, SGC	Urban Agriculture program, Transformative Climate Communities program, Affordable Housing and Sustainable Communities program, Community Composting for Green Spaces Grant Program

7 Deploy Sustainable, Adaptable, and Integrated Pest Management

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

Agricultural pests already pose serious risks to crop yields, farm economics, and food security. Worsening these existing challenges, climate change is expected to intensify these threats by accelerating pest development, expanding geographic ranges, increasing disease outbreaks, and weakening crop defenses. Rising temperatures, shifting precipitation, and elevated CO_2 in the atmosphere can increase insect reproduction, weed competitiveness, and pathogen spread all while reducing the effectiveness of natural enemies and complicating pesticide use. The result is pest outbreaks that are harder to predict and manage. Without coordinated and adaptive pest management strategies, climate-driven pest pressure could raise production costs, reduce yields, disrupt markets, and disproportionately harm small, underserved producers and low-income consumers.

This chapter explores how California is is bolstering its work on pest management, including through Integrated Pest Management framework to build long-term resilience through prevention, biological controls, research, workforce training, and reduced reliance on high-risk pesticides.

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.

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 out competing crop plants for critical resources such as nutrients, light, and water. 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.

Pest management refers to a range of practices used to control and mitigate pest pressure and damage. 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 while potentially increasing pest pressure. 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.

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

Integrated Pest Management and Sustainable Pest Management

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."[13] 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.[14] Sustainable Pest Management (SPM) is a more recent concept that emerged from a working group convened by DPR and CDFA and that was subsequently established in state statute through Assembly Bill 2113. SPM is defined in Food and Agriculture Code section 11412 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.

Stakeholder Feedback

Stakeholders request that CDFA assist DPR in providing context to their annual pesticide report numbers so that the public can see and understand what is driving headline trends.

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 many of 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.

Naval 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.[15] 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.[16] 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.[17] (See Invasive Fruit Flies call-out box for more information.)

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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).[18] 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.[19] Some weeds become more resistant to herbicides under higher CO_2 levels.[20] 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.[21] Elevated atmospheric CO_2, increased temperature, and drought stress have all been shown to increase feeding by insect herbivores.[22] 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 as well as non-pesticidal pest management options. 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.

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.

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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.

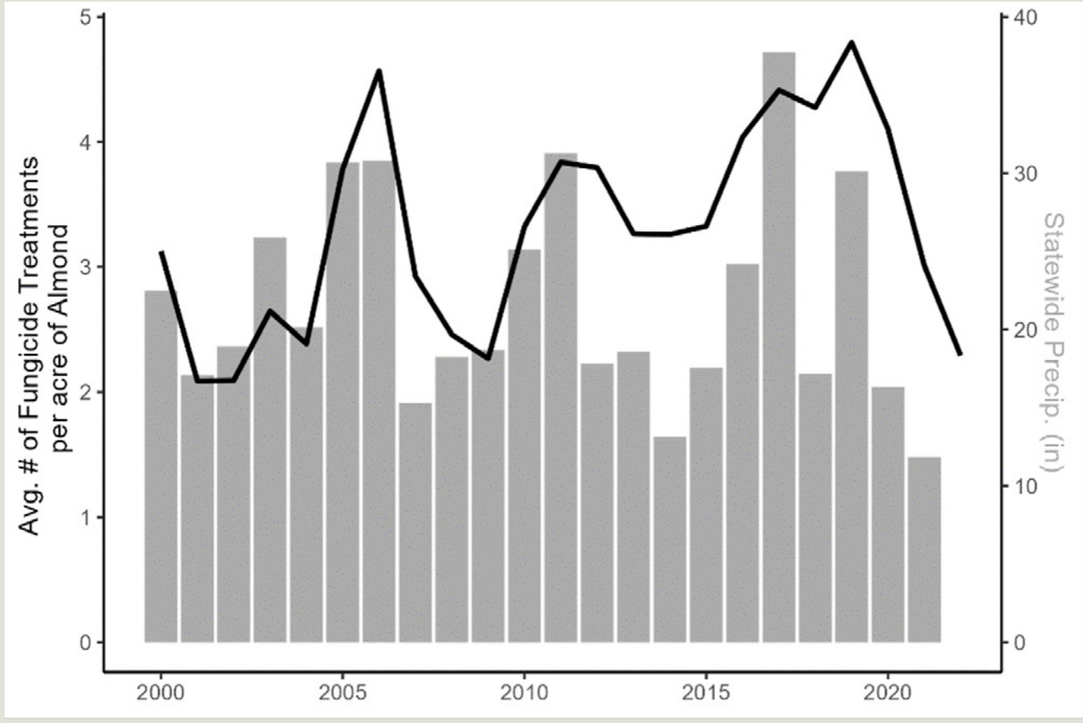

Figure 12: OEHHA Climate Change Indicators 2022; PUR 2024

Figure 12 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.

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 prevention 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 into higher elevations.[23]

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 recorded introduction of Queensland fruit fly and Tau fruit fly in the state's/nation's history. CDFA successfully eradicated all IFFs from the 2023-24 outbreak with heavy collaboration and support from USDA, County Agriculture Commissioner offices, Cooperative Agriculture Support Services, California Conservation Corps, and contractor services.

The total 2024 gross production value of 23 commodities grown in California which are hosts for the oriental fruit fly and at risk of infestation, is approximately $13.9 billion in (Table 5). Although complete crop loss may not occur, the 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.

The 2024 gross production value of California-grown commodities susceptible to invasive fruit flies is approximately $25.89 billion. This is only the value of the commodities and does not include the value of ancillary industries, value-added products utilizing these commodities, agrotourism and job creation.

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Table 5: Fruit Fly Species and 2024 Gross Production Value of Commercial Host Commodities

Fruit Fly Species	2024 gross production value of commercial commodities potentially affected by fruit flies
Mediterranean fruit fly	$19.91 billion
Oriental fruit fly	$13.9 billion
Peach fruit fly	$12.41 billion
Tau fly	$12.46 billion
Melon fly	$11.82 billion
Mexican fruit fly	$3.19 billion
Sapote fruit fly	$2.43 billion
Total CA commodity value	$25.90 billion

Note:

All Values reflect 2024 data except for one commodity (dates) where only 2023 values were available.

The total California commodity value at risk reflects the combined value of the 30 highest value 2024 commodities that serve as hosts for one or more invasive fruit fly species.

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 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. This would dramatically impact the state and country's strategic food supply. As pest pressure and the pest approach rate (rate at which new pests are being introduced into new regions) continues 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.

Stakeholder Feedback

Stakeholders suggest increasing staffing to deal with both the increasing rate of invasive species and the changes in range and behavior of established pests.

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

Goal 4: Provide Health and Environmental Benefits

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 and infrastructure.

Goal 4: Provide Health and Environmental Benefits

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 using technical assistance to facilitate widespread adoption of sustainable and integrated pest management.

Goal 4: Provide Health and Environmental Benefits

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.

Other CDFA programs also support farmers in reducing high-risk pesticide use and implementing practices that support pest predators (e.g., hedgerows) and plant health and resilience, while also increasing biodiversity and improving ecosystem services. The Organic Transition Pilot Program supports farmers in their organic transition through technical assistance and funding. OTPP has awarded $6.1 million to four block grant recipients. The Healthy Soils Program (HSP) and the Pollinator Habitat Program (PHP) support farmers in reducing high-risk pesticide use by providing technical assistance and funding for the implementation of practices that support pest predators such as hedgerows, conservation cover, and wildlife habitat (for more on PHP and HSP see Chapters 8 and 10).

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- and mid-scale farming operations, which have both greater economic barriers to implementing SPM practices and a lower threshold for accepting risk. With the majority of farms in California 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. One objective outlined in the SPM Roadmap's is to update PCA training and continuing education courses to reflect SPM principles.

Stakeholder Feedback

Stakeholders indicated that small and mid-scale farmers have both greater economic barriers to implementing SPM practices and a lower threshold for accepting risk.

Case Study: Promoting Biologically Integrated Orchard Systems Builds Farm Biodiversity

Project Funding Program: Biologically Integrated Farming Systems

Awarded Organization: Community Alliance with Family Farmers

Award Year: 2020

Project Implementation Counties: San Joaquin, Yolo, Solano, Butte

Community Alliance with Family Farmers' (CAFF's) mission "to build sustainable food and farming systems through policy advocacy and on-the-ground programs that create more resilient family farms, communities, and ecosystems" aligns well with the Biologically Integrated Farming Systems (BIFS) Program's objectives of demonstrating, refining, and providing outreach on innovative, biologically integrated farming systems that reduce chemical pesticide inputs. Led by the Director of Ecological Farming at CAFF, Sara Tiffany, and Ecological Pest Management Senior Manager, Hanna Kahl, their BIFS project was designed to foster co-learning among farmers, agricultural pest control advisors, and outreach professionals around building more sustainable farming practices and systems by "taking a participatory extension [approach that] centers farmers and their expertise, as well as their needs and interests around research, technical assistance and education on integrated pest management."

Top: CAFF team setting up research trails. Bottom: CAFF field day giving training on biologically integrated pest management in a walnut orchard.

Through this project, CAFF's Ecological Farming Team hosted field days on walnut orchards in the Sacramento and Northern San Joaquin Valleys where farmers received hands-on training for managing pests using sustainable practices such as monitoring and biological control, while receiving technical assistance and science-backed information provided by CAFF. Biological control involves releasing or providing habitat to support natural enemies that provide pest control services. This technique helps reintroduce "a balance between predator and prey". On their research and outreach sites, they explored how mating disruption can manage pests of walnut orchards like coddling moths and allow growers to significantly reduce their pesticide use, allowing for populations of natural enemies to return, especially when coupled with building healthier micro-ecologies such as through cover cropping or releasing natural enemies. This method of pest control is especially helpful in reintroducing "a balance between predator and prey" by mitigating secondary pests, which often explode in population after broad spectrum pesticide applications.

Case Study: Promoting Biologically Integrated Orchard Systems Builds Farm Biodiversity

These practices do not come without challenges. The main hurdle of implementing biologically integrated pest management is the upfront cost. Sara Tiffany explains, "Organic or biopesticides are even more expensive and usually must be applied more frequently. Practices like pheromone mating disruption [intentional interference with the chemical communication between pests needed for reproduction] are also more expensive in the short term than managing those pests with pesticides. In the case of biological control, it can be difficult to source natural enemies from insectaries and release them in a timely manner to get effective results." Tiffany shares that expanding incentives for growers could potentially make an impact and help counter the economic risk and barriers growers face when they are interested in reducing pesticide use.

CAFF's on-farm projects and events that highlight these practices create opportunities for growers to troubleshoot biologically integrated pest management practices on their farms, so they can see its potential firsthand and better understand how to navigate its challenges. Several attendees expressed interest in hosting similar field days on their sites to spread the word further.

*"**Climate resilience** for us means **building** up the **ecosystem's capacity** to be less vulnerable to short-term shocks and long-term stressors that are caused by climate change.... The **more biologically integrated** our farming systems are, the **more** we are building up **biodiversity, soil health and reducing our reliance on agrochemical inputs**.... I think we need to **invest** in finding the **synergies** between **farmer experience** and what the **research** tells us about climate resilience and how to adapt to it. The more we can **bridge** these, the more **practical solutions and innovations** we will find to benefit farmers, the environment and our food system."*

– Sara Tiffany

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

Goal 4: Provide Health and Environmental Benefits

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 nine 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, detect, and 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.

Stakeholder Feedback

Stakeholders would like to see acceleration of review and approval for safer and more effective pest management tools.

Case Study: Research on Current Grapevine Disease Occurrence May Predict Future Climate Change-Induced Spread

Funding Program: Pierce's disease and Glassy-winged Sharpshooter Board

Awarded Organization: University of California, Berkeley

Award Year: 2021

Data Collection County: Mendocino

Top: Pierce's disease in a grape vineyard (UC Berkeley). Bottom: Field sampling at the Hopland, CA field site.

Pierce's disease (PD) was first reported in California's grapevines near Anaheim around 1884. The disease is caused by a bacterium carried by pests like the glassy-winged sharpshooter. It kills grapevines by clogging their water-conducting vessels so that the diseased limbs die. Several strains of this bacterium exist, attacking and causing damage to different host plants including grapes, citrus, almonds, and certain shade trees such as oaks, maples, and sycamores. There is no known cure for PD.

Dr. Rodrigo Almeida is a Professor & Hildebrand-Laumeister Chair in Plant Pathology at University of California, Berkeley studying PD (and other agriculture-relevant diseases) characteristics since 1999. In 2021, Dr. Almeida received funding from CDFA's Pierce's disease and Glassy-winged Sharpshooter Research Board to fund a research project on potential shifts in the disease's epidemiology. By studying factors like the genetics of the infecting pathogen, the behavioral patterns of its vectors, and how environmental conditions affect California's grapevines, his research is well-suited to look at how PD may spread in the future in the face of climate change.

Evidence shows that climate change is most likely expanding the range in which PD is found. Since its discovery, PD has been reported and is known to exist in 28 counties in California; while most counties are in Southern and Central California, it can now be found as far north as Humboldt County. More moderate winter temperatures are likely to result in higher PD prevalence in Northern California. Because PD cannot survive cold winters, plants have historically benefited from a periodic recovery from infection. Concerningly, evidence shows that the infecting bacterium is adapting to warmer weather; as California faces overall warming, a wider area of cropland will likely become more susceptible to this and other diseases.

Case Study: Research on Current Grapevine Disease Occurrence May Predict Future Climate Change-Induced Spread

Studies indicate that PD accounts for more than $100 million in losses per year, from a combination of damage mitigation, production losses, and replacement of vines. CDFA's Pierce's Disease Control Program has built an exemplary reputation over more than two decades of research to identify and address the factors at play in this and other grape diseases affecting California agriculture.

*"We are **already seeing Pierce's disease expansion** into novel territories." His research at the forefront of this field may help identify techniques to help plants recover from infection. This highlights the **importance of funding basic research** to better understand risks and ultimately identify novel strategies for disease control. He proposed that Academia needs **legislative direction to spur prioritization of further research** on PD progression in the context of climate change, given the **urgency that evolving pest pressures demand**.*

– Dr. Rodrigo Almeida

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
7.1 Expand and enhance the state's ability to deploy and proactively address pest related to climate.			
7.1.1 Bolster CDFA's capacity for monitoring for, treatment, and prevention of invasive species, pests, and diseases.	4: Provide Health and Environmental Benefits	CDFA	Pest Detection and Emergency Projects Branch, Biological Control Program, Vertebrate Pest Control Research Program
7.1.2 Prepare for emergency situations with coordinated procedures and infrastructure.	4: Provide Health and Environmental Benefits	CDFA	Pest Detection and Emergency Projects Branch
7.1.3 Be proactive to threats against plant and animal health using technical assistance to facilitate widespread adoption of sustainable and integrated pest management.	4: Provide Health and Environmental Benefits	CDFA/ DPR	Office of Pesticide Office of Pesticide Consultation & Analysis, Biologically Integrated Farming Systems (BIFS), Alliance Grants, IPM Achievement Awards, IPM for Child Care Programs, DPR School IPM
7.1.4 Be proactive to threats against plant and animal health through research and predictive tool development.	4: Provide Health and Environmental Benefits	CDFA	Research Grants, OPCA IR-4 Project, Adaptive IPM for Invasive Agricultural Pests Program

8 Boost Biodiversity on Farmlands

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

Modern agriculture's focus on efficiency and uniformity has reduced on-farm biodiversity, and research shows that strategically enhancing biodiversity can strengthen ecosystem health, farm productivity, and climate resilience. California faces increasing threats from climate change, invasive species, and habitat loss. However, farms can play a critical role by providing habitat and habitat connectivity. Protecting and restoring biodiversity on and around farms supports soil health, natural pest control, water regulation, and long-term food security, making it essential for a resilient food system. California is advancing this shift through programs such as CDFA's Healthy Soils and Pollinator Habitat Programs, as well as invasive species management programs, tribal co-stewardship efforts that integrate Traditional Ecological Knowledge, and wildlife action planning. Together, these approaches aim to reframe biodiversity as a foundation of climate-smart agriculture, balancing food production with ecological stewardship to benefit both working lands and natural ecosystems.

This chapter details the ongoing and needed efforts to increase biodiversity on farms, including an increase in research, technical assistance, and collaboration on biodiversity efforts and programs.

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.[24] 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, deserts, 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. Farms are well-positioned to mitigate some biodiversity challenges from climate change, mainly by providing habitat and habitat connectivity in landscapes that lack significant natural habitat.[25]

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 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 safe 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 while maintaining the viability of agriculture. 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. In 2018, Governor Jerry Brown 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.[26]

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.
3. Enhance soil health and biodiversity through the Healthy Soils Initiative.[27]

AB 923 (Ramos, 2022), along with CNRA-led Tribal Stewardship Policy encourages state agencies to work with tribal communities for land management decisions on a tribe's ancestral lands, these consultations should bolster progress towards the state's 30x30 initiatives by better incorporating TEK into land stewardship and conservation efforts.

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.[28] 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.[29]

One of the primary mandates of CDFA is to protect against invasive species, as described in Chapter 7.[30] 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 agriculture, invasive agricultural pests can and do establish in natural environments, causing habitat loss and degradation.

Chapter 8: Boost Biodiversity on Farmlands

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 while producing safe food.

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

Goal 4: Provide Health and Environmental Benefits

FSMA directs the U.S. Food and Drug administration to set risk-based, prevention-oriented safety standards.[31] Additionally, voluntary programs set commodity-specific food safety guidelines for crop production and harvest that can include additional crop-specific or buyer-mandated requirements. Requirements from large processors, retailers, and other buyers (collectively called "buyers") are cited as the most specific and precautious.[32] Since these buyers constitute most of the market, most farms are held to their strict requirements, otherwise they risk rejection of crops if the buyers' safety requirements are not met.[33] This pressure can constrain a grower's ability to implement environmentally sustainable practices.

Conflicts between food safety requirements and environmentally sustainable practices can be costly for growers. No-harvest buffers can lead to unharvested crops; eight percent of surveyed growers experienced crop rejection due to practices utilized to improve water quality or wildlife habitat.[34] This conflict can lead to growers who want to implement sustainable practices to choose not to.[35]

Pressure from food safety requirements may continue to increase with climate change because the risk of pathogen contamination of produce may be increased by climate-driven events such as more frequent and intense rainfall, recurring floods and drought, and rising temperatures.[36] This again presents an opportunity for providing outreach, education and technical assistance to farmers in an integrated manner, where assistance related to biodiversity-boosting conservation practices can go hand-in-hand with food safety knowledge, and help farmers implement strategies that address both needs.

Stakeholder Feedback

Stakeholders called for more research and outreach to be done around how to integrate more biodiversity on farms without compromising food safety.

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

Goal 4: Provide Health and Environmental Benefits

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.[37] 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.[38] (For more information on pest management, see the Pest Pressures Chapter.)

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 4: Provide Health and Environmental Benefits

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 and preserving and enhancing habitat. 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 (OTPP). 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 $1 million contribution for additional technical assistance and long-term research from 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 Climate-Smart and 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.

Stakeholder Feedback

Stakeholders suggested expanding CDFA's Pollinator Habitat Program to support a landscape-scale strategy where pollinator and wildlife corridors are planned and incentivized at the landscape scale, rather than farm-by-farm. Stakeholders note a missed opportunity to collect long-term biodiversity data from the Pollinator Habitat Program. They recommend CDFA establish a statewide effort to evaluate biodiversity outcomes from past PHP projects and use findings to inform future program design.

Stakeholders suggest additional actions to increase beneficial biodiversity and improve seed supply. They recommend strengthening this by prioritizing on-farm habitat enhancements (e.g., native hedgerows, corridors, pollinator habitat) that co-benefit soil health, water infiltration, carbon sequestration; including metrics for soil biodiversity, microbial diversity, arthropod beneficial insects, not just crop biodiversity; and ensuring funding streams for long-term biodiversity monitoring on farms, especially for small and diverse farms transitioning to regenerative systems.

PHP, OTPP, and HSP are all incentive programs administered by CDFA's Office of Agricultural Resilience and Sustainability (OARS). These incentive programs are meant to lessen financial barriers to implementing practices that, in this case, support increasing biodiversity on farms among other benefits. This can be particularly important for long term habitat projects just as hedgerows and wildlife habitat plantings. Small farms and those on short term leases can struggle to implement these longer-term practices. The block grant structure of many of OARS' incentive programs including the Healthy Soils Program and Pollinator Habitat Program allows for trusted community-based organizations to provide technical assistance directly to small and urban farmers, to meet these farmers where they need assistance, and to tailor the program for the farmers they work with closely.

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.[39] Unfortunately, 90 percent of California's riparian areas are degraded.[40] The California Department of Conservation's Working Lands and Riparian Corridors Program (WLRC) has awarded funds for watershed restoration planning and implementation on agricultural lands. 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.

Case Study: Establishing Pollinator Habitats on Active Farming Operations

Project Funding Program: Pollinator Habitat Program

Awarded Organization: Xerces Society, Inc.

Award Year: 2023

Project Implementation Counties: Monterey, San Benito

Top: Pollinator and beneficial insect habitat on active farmland in Monterey County. Bottom: Native bee and ladybug pupa on seaside daisy at Taylor Farming PHP site.

California's native pollinators such as bees, butterflies, and other species play a critical role in the productivity of many agricultural crops and the health of natural ecosystems. However, pollinator populations are facing rapid population declines due to several factors including habitat loss, disease, impacts of climate change, and lack of integrated pest management, which seeks to minimize the effects of pesticides on pollinators. The Pollinator Habitat Program (PHP) block grant supports the creation of habitats on agricultural land that provide critical floral resources and host plants for pollinators and other beneficial species. In addition, participating growers will be trained on integrated pest management. Beyond habitat creation, these plantings provide environmental co-benefits, including enhanced biodiversity, improved soil health, pest control, improved water quality, and increased carbon sequestration.[41]

One PHP block grant recipient is the Xerces Society for Invertebrate Conservation (Xerces Society), an international non-profit that protects the natural world through the conservation of invertebrates and their habitats. Their Living Farms Project works directly with food companies and farmers to re-integrate nature into farms through hands-on field restoration services. Research shows that high-quality pollinator habitat integrated into agricultural landscapes can have a meaningful impact on pollinators and other biodiversity.[42] PHP provides a unique structure that gives Xerces Society and its partners in the agricultural community the opportunity to increase the impact, speed, and scale of conservation implementation of California's agriculture.

Pam Silkwood is the Compliance Officer for Taylor Farming LLC, one of Xerces Society's PHP block grant beneficiaries in Monterey and San Benito Counties. She has noted various direct and indirect benefits of this project: "While our specialty crops do not require pollination, fostering a diverse insect community helps maintain ecological balance and supports overall farm health.... By integrating [pollinator] shrubs in strategic locations, Taylor Farming aims to establish long-term [habitat] corridors that contribute to both agricultural resilience and environmental health."

*"To [Taylor Farming], **climate resilience** means the ability to adapt to and **withstand the increasing challenges** posed by climate change while continuing to maintain productive and sustainable farming operations." Xerces Society agrees: "[t]hrough habitat restoration that focuses on the farmers' goals and native pollinators, our work helps **stabilize crop production and improve the long-term viability of farming**. Nationally, because California produces a significant share of the country's fruits, nuts, and vegetables, safeguarding pollinator health here helps **ensure food security** across the U.S. and reduces the effects of agricultural disruptions in these critical growing regions. **Investing in pollinator habitat** is a strategic move to build a more resilient and sustainable agricultural system from the ground up."*

– Xerces Society and Pam Silkwood

Janae McCarthy is Xerces Society Pollinator Habitat Specialist in Fresno working directly with growers to plan and plant the pollinator habitats.

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, $107.7 million 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.[43] 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.[44] 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.[45]

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

Goal 4: Provide Health and Environmental Benefits

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.

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.[46]

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 that 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 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.[47]

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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. The Fish Food on Floodplain Farm Field Project is a collaborative project that includes 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.[48]

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

Goal 4: Provide Health and Environmental Benefits

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. It was 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 guidelines and identify research

Stakeholder Feedback

Stakeholders suggest expanding to include native plant seeds, on-farm seed banks, farmer-led seed networks, and support for heirloom/regionally adapted cultivars that enhance resilience. They note that the availability of native seeds is dependent on a supply chain that includes tribes, on-farm seed banks, farmer-led seed networks, and support for heirloom/regionally adapted cultivars that enhance plant resilience.

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 Design guiding principles to support biodiversity and agriculture.

Goal 4: Provide Health and Environmental Benefits

To better coordinate actions that lift up agricultural solutions to enhance biodiversity, the department will create a biodiversity and agriculture guiding principles document. This will guide CDFA's program development, engagement in workgroups, and other biodiversity-related actions.

8.2.5 Support research that addresses uncertainties around biodiversity, agriculture, and climate.

Goal 4: Provide Health and Environmental Benefits

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 integrates 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 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 on costs is critical for advancing adoption–the cost of implementation, at the practice scale and also whole-farm impacts, and across California's multitude of growing regions and crop types will help farmers make informed decisions. Research is also needed to better understand climate-driven changes in hydrology to better mitigate impacts from longer droughts and wetter storms 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.

Stakeholder Feedback

Stakeholders recommend ensuring that biodiversity enhancement efforts do not conflict with FSMA and LGMA requirements, and including farmers in outreach to balance biodiversity goals with food safety compliance.

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 due to climate change and some land management practices compromises critical ecosystem functions.[49] 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 department's Science Advisory Panel (SAP) on Resilience and Sustainable Agriculture, commissioned 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 play an important role in 2023. The assessment provides targeted recommendations for policymakers and stakeholders to enhance soil health and conserve biodiversity, which play 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.[50] 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.[51] 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.

8.2.6 Implement policies that support incorporating biodiversity to improve climate resiliency on-farm.

Goal 4: Provide Health and Environmental Benefits

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 30x30 efforts. Sustainably 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.[52] 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.[53]

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.[54] 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.[55] 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.[56] 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.[57]

Chapter 8: Boost Biodiversity on Farmlands

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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.	4: Provide Health and Environmental Benefits	CDFA	Food Safety Modernization Act (FSMA) Technical Assistance Program
8.1.2 Increase knowledge of best practices to manage pests while minimizing damage to biodiversity.	4: Provide Health and Environmental Benefits	EPA, DPR	DPR Endangered Species Program, IPM technical assistance resources
8.2 Increase beneficial biodiversity on farms.			
8.2.1 Utilize programs to effectively build and protect biodiversity on farms.	4: Provide Health and Environmental Benefits	CDFA, CDC, WCB, DOC, CNRA, USDA	The Pollinator Habitat Program (PHP), Organic Transition Pilot Program (OTPP), Healthy Soils Program, ERAL Program, Voluntary Local Programs, Working Lands and Riparian Corridors Program, California Riparian Habitat Conservation Program, Tribal Nature Based Solutions Grant Program, Regional Conservation Partnership Program (RCPP)
8.2.2 Convene committees and coalitions to identify pathways to build biodiversity on farms.	4: Provide Health and Environmental Benefits	CDFW	California Biodiversity Network, Monarch Butterfly - MultiAgency Collaborative Working Group, The California Pollinator Coalition, Tricolored Blackbird Working Group, Floodplain Forward Coalition, Nigiri Project, Fish Food on Floodplain Farm Fields, San Joaquin Valley Monarch Recovery Strategy, Grasslands Wildlife Management Area (WMA)
8.2.3 Understand the need for seed supply to support biodiversity efforts across the state.	4: Provide Health and Environmental Benefits	CNPS	California Native Seed Strategy

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
8.2 Increase beneficial biodiversity on farms.			
8.2.4 Design guiding principles to support biodiversity and agriculture.	4: Provide Health and Environmental Benefits	CDFA	
8.2.5 Support research that addresses uncertainties around biodiversity, agriculture, and climate.	4: Provide Health and Environmental Benefits	DPR, OPCA	Emerging Technologies Workgroup (ETW), OPCA reports on food safety, bee protection, and pest management, Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment
8.2.6 Implement policies that support incorporating biodiversity to improve climate resiliency on-farm.	4: Provide Health and Environmental Benefits	CDFW, CNRA	30x30 California, California State Safe Harbor Agreement (SHA) Program

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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.

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.

California's most productive agricultural regions face some of the nation's worst air quality. Geographic factors, heavy transportation corridors, and agricultural activities are all contributing factors that are creating serious health risks for farmers, farmworkers, and nearby communities. Climate change is intensifying impacts through drought, extreme heat, wildfire smoke, and dust, resulting in increased pollutants that harm human health, damage crops, and disproportionately burden low-income and disadvantaged communities.

This chapter explores how California is implementing stricter air quality standards, phasing out agricultural burning, promoting cleaner equipment and zero-emission technologies, supporting alternative residue management and manure treatment, and advancing dust mitigation and wildfire response efforts to improve air quality, protect public health, and support a more resilient agricultural system.

Context

In California, some of the most productive agricultural areas, particularly the Central Valley, are also amongst the most polluted areas in the nation.

The mountain ranges encompassing the Central Valley trap air pollutants emitted from heavy truck 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.[1] Contamination of the air with pollutants like ozone, fine particulate matter (PM2.5), coarse particulate matter (PM10), nitrogen oxides (nitrogen oxides, or NOx, typically formed through anthropogenic activities like fossil fuel combustion, but lightning strikes and soil microbial emissions from fertilizer use are also sources), carbon monoxide, sulfur oxides, volatile organic compounds (VOCs), 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.[2]

While a highly productive farming region, the Central Valley registers highly for pollution impacts on the CalEnviroScreen 4.0 map, which helps identify communities disproportionately burdened by pollution. In the Central Valley, one in six children suffer from asthma.[3] The Central Valley is also home to one of the state's highest 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 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.[4] 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.[5] Nitrogen oxides directly damage plants and hurt yields, can also mix with ammonia to create an aerosol compound that is a main component of PM2.5 in the valley, and can scatter sunlight and reduce plant growth and yields.[6]

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 the California Air Resources Board (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 NOx.

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 NOx in the exhaust.[7]

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. As of March 2025, development of the Mobile Source Strategy is paused to reconsider the approach.

Non-Mobile Sources: Agricultural Burning, Dust, and Fertilizer

Management of agricultural waste is critical for maintaining productive operations. "Agricultural waste" refers to the residues generated from farming, livestock, and food production activities. This includes crop residues, or materials left over after harvest; animal waste, e.g., manure; and processing waste. As discussed in Chapter 1, there is a concerted effort to re-conceptualize agricultural waste as useful inputs to return to the soil and/or for innovative products in a 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 disposal method; however, the combustion of these materials releases fine particulate matter such as PM2.5.[8] 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.[9] Furthermore, this program has expanded the options for handling crop residues for growers, making transitioning away from open burning more feasible.

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 managed to produce biochar, a charcoal-like substance that can be used as a soil amendment.[10] However, the quality of the biochar produced should be tested before it is applied to the soil.

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 anaerobic decomposition of organic material, which releases methane.[11] Dairy digesters provide a pathway for manure processing to capture methane, reducing the greenhouse gas emissions from dairy operations as well as local particulate emissions that can affect nearby communities. However, traditional biogas combustion technology for electricity generation powered by digesters have received criticism for potentially increasing criteria pollutants directly and indirectly, including NOx and PM2.5 in communities proximal to the dairy digesters. Other digester biogas utilization options, such as biomethane injection into natural gas pipelines or biomethane use in solid-oxide fuel cells or linear generators provide alternatives to combustion engines and have fewer localized emissions. Although biofuels such as biomethane can have negative carbon intensities, biofuels based on purpose-grown-crops could result in net positive carbon impacts.[12]

In addition, the over-application of nitrogen fertilizer can lead to nitrous oxide and ammonia emissions.[13] Efficient 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 leading to environmental contamination including degradation of groundwater and air quality.[14] 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 that the California Emissions Projection Analysis Model (CEPAM) that CARB is using to predict soil NOx emissions is likely underestimating the contribution of microbial emissions of NOx from soils and recommends additional data collection to better validate modeling results.[15]

Dust

Though the term "dust" may 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.[16] 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, as well as 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 traditional almond harvesting, which requires the shaking of almonds to the ground and then sweeping them up. Many of these activities produce significant dust, including particulate matter like PM2.5 and PM10. There is also growing concern about dust created as farms are left fallow as a result of drought or other factors.[17]

Dust and Valley Fever

Valley fever (coccidioidomycosis) is a respiratory illness caused by inhaling spores of the soil-dwelling fungus Coccidioides found in arid or semi-arid regions of California, especially the Central Valley, San Joaquin Valley, and Central Coast. When inhaled, Coccidioides can infect the lungs and cause symptoms such as cough, difficulty breathing, fever, and fatigue. Spores can become airborne when soil is disturbed by wind, construction, or agricultural activities such as tilling or harvesting, posing health risks to workers and nearby communities.

Climate change is intensifying conditions that favor the spread of Valley fever by creating hotter, drier weather, driving cycles of prolonged drought followed by heavy rain that promote fungal growth, and increasing the frequency and intensity of dust storms that can spread spores over wider areas. These changes are contributing to an expansion of the disease's range and a rise in cases. Since 2017, California has reported between 7,000 and 9,000 cases annually. Implementing dust mitigation practices in agriculture can help reduce the risk of exposure while providing the co-benefit of improved air quality.

For additional information on Valley fever visit the California Department of Public Health Valley fever website.

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.[18] 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.[19]

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.[20]

Wildfire 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.[21] 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.[22]

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.[23] They also found that as fallowed land areas increased between 2008 and 2022 due to drought, there were more incidences of dust storms. Their research showed 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 1930s, 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 NRCS 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 protect 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 on cover cropping indicates that water evapotranspiration, or the water that evaporates from the soil and is transpired through the plant 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.[24]

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 assumption that additional water was 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 provided information on 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.[25]

Strategies and Actions

Limited funding for agricultural equipment and limited technical assistance can pose barriers for agricultural operations trying to make improvements that reduce air pollution. The actions listed below describe the opportunities 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 implement 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 results in a significant financial barrier.

To address the air quality concerns stemming from agricultural operations, further research into sources and solutions 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 on air quality impacts related to agricultural operations.

Goal 4: Provide Health and Environmental Benefits

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 a series of multi-year strategic plans informed by the public to address pertinent research needs regarding air quality.[26] 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 to 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 topics include air quality and mobile sources. Research findings result in five additional dollars for each dollar CARB invests, supporting climate, environment, and health.[27]

Stakeholder Feedback

Stakeholders suggested including cost-benefit analyses for potential improvement strategies for agricultural impacts on air quality.

9.1.2 Coordinate outreach about state programs between state agencies.

Goal 1: Improve the Bottom Line for Farmers

Implementation of management practices and installation of upgraded equipment requires technical assistance to reach the appropriate audiences and provide the needed information for transitioning 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 1: Improve the Bottom Line for Farmers

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.[28] 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 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. Created in 1998, this program has encumbered over $1.31 billion in

Stakeholder Feedback

Stakeholders support programs that increase access to equipment upgrades and improve agricultural operation practices that can improve air quality. Stakeholders emphasized the importance of increasing accessibility of these programs to all growers, including those with less resources or operating smaller farms, citing programs such as UCDA NRCS' Combustion System Improvement Tractor Replacement Program as one example to learn from.

"FARMER, in partnership with the Carl Moyer Program, has proven to be one of the most cost-effective programs for reducing criteria pollutants in California. San Joaquin Valley growers, many operating within the boundaries of disadvantaged communities, have achieved remarkable results: over 12,000 tractors replaced, eliminating more than 11 tons per day of criteria pollutants."

funding which resulted in almost 70,000 projects implemented, 191,000 tons of NOx reductions, and 7,440 tons of PM reductions.[29]

Funding Agricultural Replacement Measures for Emission Reductions (FARMER) was established in 2018 and supports the agricultural sector's transition to 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's 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.[30]

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 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.[31]

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.[32] 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. Other management practices such as reduced or no-tillage and cover cropping can help prevent wind soil erosion and cut down on dust in the air.[33]

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.[34] (*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.)*

CDFA's Fertilizer Research and Education Program also holds an annual grant solicitation to fund outreach, education, demonstration, and research projects addressing environmentally safe and agronomically sound use and handling of fertilizers. Ongoing priorities include research addressing gaseous losses from NOx and ammonia (as well as nitrous oxide) and identifying mitigation strategies to reduce emissions.

A significant barrier to the phase-out of agricultural burning is a lack of equipment needed for low-dust harvesting equipment, as well as equipment for grinding, chipping, shredding, and incorporation into the soil.[35] 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.

Stakeholder Feedback

Stakeholders are supportive of programs that help growers handle utilize agricultural waste in economically viable ways that improve air quality and recycle nutrients. Stakeholders would like to see research and demonstration projects that improve agricultural waste management and also support the creation of regional biomass utilization and processing facilities.

Stakeholders also look forward to CDFA's forthcoming equipment-sharing program as a potential source of resources to increase access to equipment and practices that improve air quality.

Case Study: California Air Resources Board Aids the Farm Equipment Energy Transition

Common agricultural machinery, such as water pumps and tractors, commonly use diesel-powered engines that give them high reliability and lower cost, but ultimately pose **serious health risks** to farmers, farm workers and surrounding communities. In 2017, California Air Resources Board (CARB) was charged with reducing greenhouse gas (GHG) emissions from agricultural equipment. The resulting program, **Funding Agricultural Replacement Measures for Emission Reductions** (FARMER) partners with local air districts to fund the adoption of decarbonized on-farm machinery which function comparably to their diesel counterparts.

Erin Uchida is a Staff Air Pollution Specialist in the Emerging Technologies & Programs Section of CARB's Mobile Source Control Division. She helps implement the FARMER program by developing program guidelines for regional air districts' funding allocations, managing administrative requirements, and providing insight on projects' methodologies for calculating emission reductions.

"[T]he FARMER Program has increased funding to encourage farmers to adopt zero-emission equipment, incorporated provisions to account for and incentivize projects that result in efficiency gains and provided air districts with the flexibility to fund [the purchase of] more functional…equipment." The program has funded the deployment of 4,000 pieces of zero emission equipment for farmers to try out before committing to the cost. This includes Utility Terrain Vehicles, electric irrigation pumps, and power line extensions. It has also supported funding for the demonstration of emerging technologies to combat air quality issues, like zero-emission tractors at a variety of farms in California.

Incorporating public concerns about ensuring equitable opportunities to access funding for all farmers, CARB provided lightly used equipment to be purchased at a discounted price through the incentives. "As of September 2024, the FARMER Program has reduced over 1,800 tons of fine particulate matter…, 30,600 tons of nitrogen oxides, and 423,000 metric tons of carbon dioxide equivalent greenhouse gases." Farmers are themselves noting that the **program allows them to more easily balance** their financial needs with the State's sustainability goals.

CARB staff who work on air district-run incentive programs (FARMER, Carl Moyer, and CAP incentives), as well as some of the Air District staff that implement these programs.

Case Study: California Air Resources Board Aids the Farm Equipment Energy Transition

Former CARB Chair Liane Randolph at a Fresno County tractor crushing event after the recycling center transitioned from diesel-burning to zero-emission equipment in 2022.

*"The FARMER program has been **instrumental** in the turnover of the legacy diesel fleet in California by **encouraging farmers** to adopt the cleanest available equipment, while providing **cost-effective emission reduction for California**…70 percent of the funding has been invested in **disadvantaged and low-income communities**, with more than **one third of projects being awarded to [small-scale farmers].**"*

– CARB

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
9.1 Improve air quality from agricultural operations.			
9.1.1 Support research on air quality impacts related to agriculture operations.	4: Provide Health and Environmental Benefits	CARB	
9.1.2 Coordinate outreach about state programs between state agencies.	1: Improve the Bottom Line for Farmers	CARB	
9.1.3 Increase access to equipment upgrades and changing agricultural operation practices that improve air quality.	1: Improve the Bottom Line for Farmers	CARB, EPA, CDFA	Carl Moyer Program, FARMER Program, Clean Off-Road Equipment Voucher Incentive Project (CORE), Community Emission Reduction Program, Targeted Air Shed Grants program, Healthy Soils Program, Pollinator Habitat Program, State Water Efficiency and Enhancement Program, Alternative Manure Management Program, Dairy Digester Research and Development Program, Dairy Plus Program

10 Advance Climate-Smart and Healthy Soil Practices

Key Objective: Meet state nature-based solution climate targets and support healthy and resilient soil ecosystems for growing food and fiber.

As the foundation of productive, resilient, and sustainable agriculture, healthy soils create living ecosystems that support plants, animals, and people. Beyond benefiting crops, healthy soil can also benefit water quality, air quality, and help with climate mitigation. Farmers and ranchers can build soil health through practices such as cover cropping, compost and mulch application, crop rotation, reduced tillage, managed grazing, and integrating plants or livestock in ways tailored to local soils and climates. These climate-smart practices align with California's conservation and climate targets but must be adapted to specific farm conditions to be effective. Drought, extreme heat, and intense rainfall threatens soil health by reducing organic matter, increasing erosion, and disrupting soil structure, making the adoption of soil-building practices essential for long-term agricultural resilience.

This chapter explores how the state is promoting increased 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.

Context

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.[36] Soils are a mixture of minerals, organic matter, including (micro)organisms, liquids, and gases that support the life of plants and animals. 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 is generally well structured, 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, increase infiltration, and enable greater biological activity as compared to compacted, less aggregated soil. Increased biological activity, including plant root growth, higher biological diversity, and potentially biomass inputs, will also generally increase the soil's organic matter, which in turn boosts nutrient cycling beneficial for crops, and also feeds back to improved aggregation and better soil structure.

Healthy soils also have benefits beyond crop production. 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 generally 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 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 land management systems. In row crop systems, effective practices include: planting cover crops or applying compost and mulch to increase soil organic matter, 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, including of native plants to build up biodiversity and create habitat for pollinators; and, reducing or eliminating tillage to minimize soil disturbance, preserve soil structure, and reduce erosion. In orchards, there may be additional opportunities to reduce tractor passes, or use livestock like

ACREAGE TARGETS

Nature-Based Solution (acres/year)	2030	2038	2045
Healthy Soils Practices • Implement healthy soils practices on annual and perennial croplands, such as compost application, cover cropping, hedgerows/windbreaks, no and reduced till, riparian buffers, whole orchard recycling, etc.	140K	190K	190K
Conservation • Conserve annual and perennial croplands	12K	16K	19.5K
TOTAL acres/year	152K	206K	209.5K
Percentage Targets	2030	2038	2045
Convert conventional to organic systems in annual and perennial croplands	10%	15%	20%

Figure 13: Nature-Based Solutions Acreage Targets

sheep or goats for weeding or mowing, as well as returning orchard biomass to the soil via chipping of prunings or whole orchard recycling. On grazing land, ranchers can plant trees or shrubs and use practices like prescribed grazing to strategically move animals through pastures, giving the soil and plants time to recover between grazing periods, and depositing manure more evenly *(for more climate-smart agriculture solutions on rangeland, see chapter 11 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 associated 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.

In 2024, the state released a set of Nature-Based Solutions targets, as required by AB 1757. Several targets were set for croplands and grasslands that require increasing healthy soils practices and conserving agricultural lands. See Figure 13 for details.

Principles of Soil Health

The USDA Natural Resources 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, moderates temperatures, suppresses weed growth, prevents erosion, helps create 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 avoid destruction of soil aggregates (clumps of soil formed by physical, chemical, and biological activity) and pore spaces that allow oxygen, water, and nutrients to pass through, and avoids the breakdown of 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 soil biodiversity can help build resilience to stressors and support the long-term health and functioning of soils.

Chapter 10: Advance Climate-Smart and Healthy Soil Practices

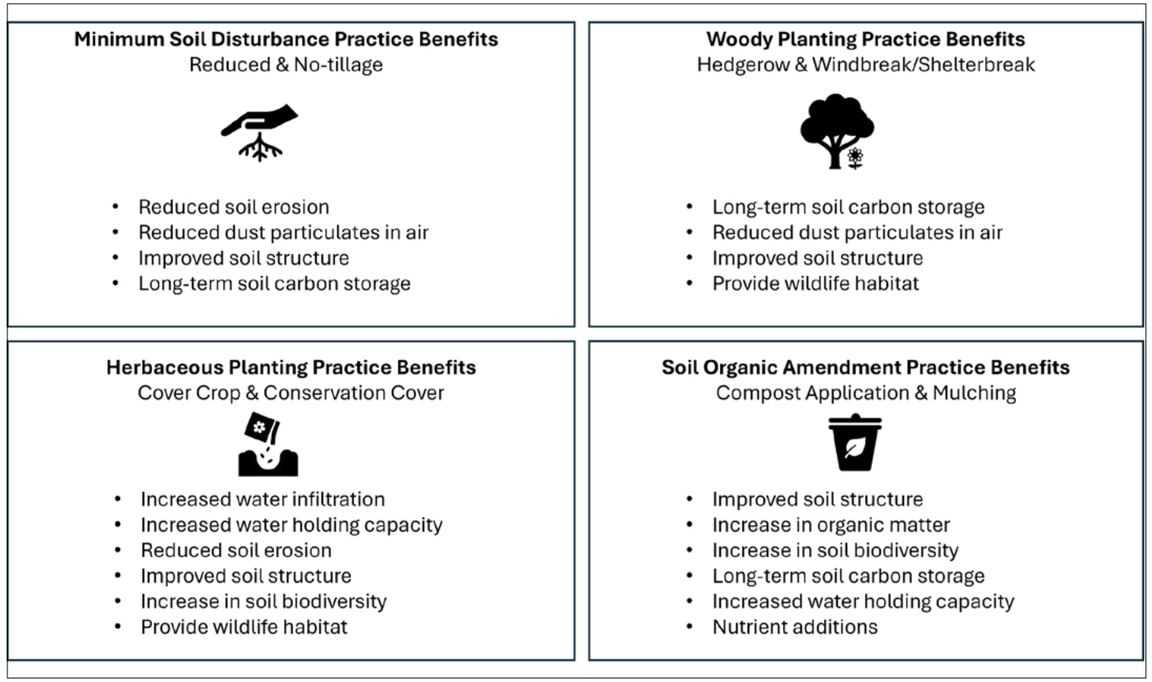

Figure 14: Healthy Soils Practices

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.[37] 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 14, healthy soils practices also have been shown to have several positive benefits that make agricultural systems better able to adapt to our changing climate. Examples of outcomes from utilizing healthy soils practices include increasing soil organic matter, which 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 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 another location. 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.[38] 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, degrading the soil structure, and reducing the binding capacities of soils.[39]

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 losses associated with decomposition rates of organic matter and carbon within the soil.[40] 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 Precipitation and Flooding

Heavy precipitation events, while sometimes relieving dry conditions, can also cause problems for soil. 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.[41] 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.[42] Even if the crop remains harvestable, 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.

Chapter 10: Advance Climate-Smart and Healthy Soil Practices

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 through the state's farmers and ranchers.

10.1.1 Coordinate state agency efforts to improve soil health.

Goal 4: Provide Health and Environmental Benefits

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.

Stakeholder Feedback

Stakeholders suggest a statewide market analysis of the organic sector to help growers make informed business decisions regarding the adoption of organic practices and the transition to organic production.

Stakeholders would like to see coordination between the State Water Resources Control Board and CDFA to help meet AB 1757 goals for healthy soils practice adoption and Irrigated Lands Regulatory Program (ILRP) water quality goals while reducing regulatory workload, especially for underserved, small, mid-scale, and diversified growers. They also suggested that ILRP could be used as an incentive platform for encouraging compost and covering crops.

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 overdrafted 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.

Continued collaboration with federal, state, regional, and local organizations, local vendors and farmers and ranchers in the surrounding areas will ensure proper practice selection and implementation for agricultural operations in the delta, as well as for project support and assistance and to ensure all local and state ordinances are followed.

10.1.2 Facilitate the adoption of climate-smart and healthy soils practices by farmers, ranchers, and private landowners.

Goal 2: Reduce Greenhouse Gas Emissions

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 appropriations totaling $205.5 million to date, as well as $10 million from Proposition 68. A further round of support from Proposition 4 is expected to exceed $40 million. To date, the program has funded healthy soils practices on 2,200 farms, reaching almost 190,000 unique acres.

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 be set for each land type. The targets for croplands require significant additional 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.[43]

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 applying to the program less intimidating, provide expert advice, and increase success; or
3. Funding on-farm demonstration projects that conduct research and/or showcase these practices.

HSP initially awarded 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 and help them manage their grants. 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 increase GHG mitigation, whether through emissions reductions or increases in carbon sequestration.

Within the program, the most commonly selected practices have been compost application, cover cropping, and hedgerow planting. In the recent round of Block Grant Pilot funding, the numbers of fields supported for each practice can be found in Figure 15.

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 applicants, grantees, and HSP staff alike and has been critical to the success of the program.

Stakeholder Feedback

Stakeholders note that currently, the Healthy Soils Program is limited to applicants who are adopting practices for the first time, and there is a lack of incentives for the ongoing maintenance of soil health practices. This issue is discussed in Chapter 1, Section 1.5.

(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, that 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'

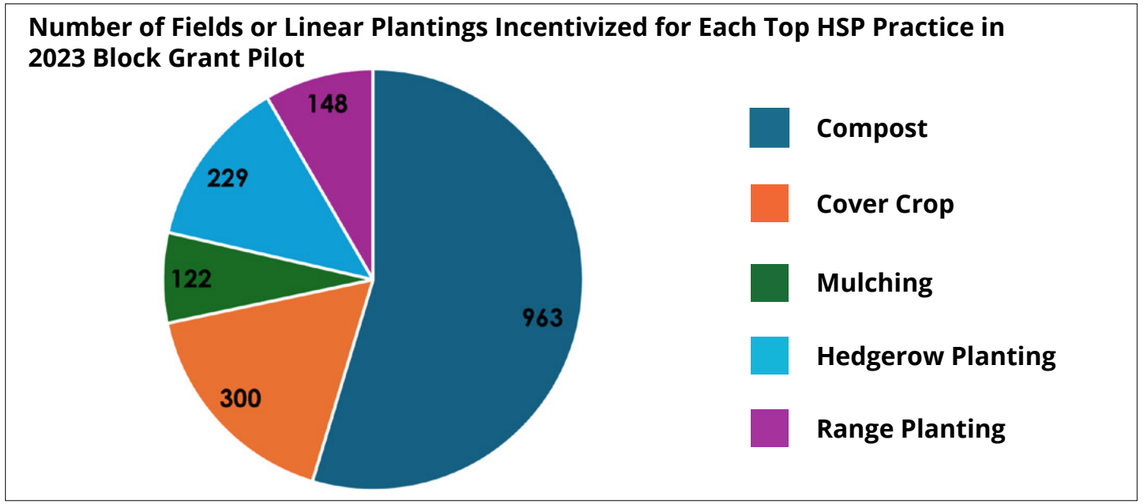

Figure 15: HSP Block Grant Fields

efforts already in place to help mitigate climate change.[44] While climate action plans have historically focused only on emissions reductions, some counties have begun representing climate-smart agriculture and carbon sequestration in 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, 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 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.[45] It also avoids emissions of GHGs and black carbon associated with the more conventional disposition—burning.

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. Seven of these "hubs" 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. Likewise, the Soil Health Center at UC San Diego is supporting demonstration grants and associated k-undergraduate educational experiences.

Chapter 10: Advance Climate-Smart and Healthy Soil Practices

The CDFA Healthy Soils Program Block Grants will allow regional awarded organizations to focus on Objectives that are regionally appropriate, recognizing that agricultural challenges, resources, and the availability of off-farm organic amendments differ widely.

Federal Efforts

At the federal level, recent policy changes have shifted funding priorities and sources relevant to 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 USDA-NRCS's 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. The conservation plans can help address on-farm resource issues and have environmental benefits such as improving soil health. These two NRCS programs are expected to continue, but now under the Farm Bill, with apparent increases in funding per year and increased minimum payments for CSP.[46] Total IRA funding for conservation will decrease by $1.795 billion.[47] Soil monitoring programs from previous administrations are under review and appear to not have funding attached as of now.[48]

Additionally, some funds like Trade & Ag Research Funding Boosts could be used for climate-resilient crops.[49] These conservation plans can help address on-farm resource issues and have environmental benefits such as improving soil health. These two NRCS programs are expected to continue, under the Farm Bill with apparent increases in funding per year and increased minimum payments for CSP.[50] Total IRA funding for conservation will decrease by $1.795 billion.[51] Soil monitoring programs from previous administrations are under review at the time of writing, and do not appear to have funding.[52] Additionally, some other funds, like Trade & Ag Research Funding Boosts, could be used for climate-resilient crops.[53]

Stakeholder Feedback

Stakeholders indicated new local/regional actions in plan to increase regional capacity to develop, prioritize, and implement agriculture climate resilience projects and free technical assistance.

Case Study: A Holistic Ecosystem Perspective Cultivates Healthy Soil

Project Funding Program: Healthy Soils Incentives Program

Awarded Organization: 2009 John Williams Eilers Rev Trust

Award Year: 2022

Project Implementation County: San Joaquin

Franz Eilers is a grantee of the 2022 Healthy Soils Program, incorporating on-farm compost production and application into his walnut orchards that are planted either fully as walnut trees or inter-planted with cherry trees. Eilers created on-farm compost for his organic farm using waste from his orchard and other local agricultural operations that he returns to the orchards. The aim is to minimize off-farm inputs and to enlarge the intrinsic nutrient and carbon base within the farm's system.

Eilers is fascinated by the intangible aspects of farming, whether that means contemplating the nature of lifeforms or recognizing that composting is more comprehensive than formulaically identifying the best soil amendments to apply and grow the most impressive crops. His approach to project implementation focuses on the natural world as being more than its constituent parts.

Franz has found that seasonal cycles also play a large part in composting effectiveness—laying compost in the fall rejuvenates the soil to serve as a foundation for a healthy ecosystem supporting summer crops. He has also found indirect benefits from his holistic approach to farming, like needing to mow the land less frequently after his operation brought in a sheep herd to biologically manage vegetation between his orchard rows.

Top: Composting equipment converting organic material into soil. Bottom: Nutrient rich soil amended with compost made on-farm.

Climate resilience to Franz Eilers reflects a bigger picture than just the implementation of one practice. With farmers' profit margins shrinking, there is very little room to accommodate unexpected events like climate disasters that drastically affect their financial bottom line. Incentives for climate-smart agricultural practices can help boost a holistic resilience of the ecosystem to climate change and help farmers financially weather the storm.

*"There's gotta be a way to **expand people's experience** of their **relationship to the soil**. It really starts there… [We need to see the soil] as **something that's alive**, like a plant…*

***[W]ithout** these **grants** these last couple of years, I really don't know what kind of situation [I would be in]. That's really from the heart…I really want lawmakers and the public to know that…**your money was spent really well** because it's the hardest thing for a farmer to…be forced to quit. [So I want to show] some **genuine appreciation** for being part of this program."*

– Franz Eilers

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 the impact of these efforts.

10.2.1 Adopt long-term indicators to measure and monitor the impact of healthy soils practices over time.

Goal 4: Provide Health and Environmental Benefits

Long Term Soil Health and Organic Matter Data Collection and Analysis

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—four 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 organic matter. However, research has shown that while soils with lower SOM may see changes within 3-5 years with soil health practice implementation, soils with higher initial SOM may take 7-10 years, or even longer, to show changes. Additionally, early HSP SOM data is inherently variable due to inconsistencies in sampling methods, sample locations, and the use of different laboratories used to conduct the analyses.[54] 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 build 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 the 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.

Statewide, AB 1757 mandated the creation of Nature-Based Solutions Targets. For croplands, these targets include implementing more than 3 million acres of healthy soils practices on the landscape by 2045. Following on from these targets, CARB is charged with developing standard methods to consistently track greenhouse gas (GHG) emissions and reductions, carbon sequestration, and where feasible, additional benefits from natural and working lands over time. To this end, CARB is coordinating work to incorporate remote sensing, reported land management data, and other state-wide agronomic and field data to understand how healthy soils practices will influence cropland carbon stocks and cropland GHG emissions over time. Foundational to this effort is the Natural and Working Lands (NWL) Carbon Inventory, which tracks carbon stocks in different natural and working landscapes over time. The NWL Carbon Inventory is designed to track ecosystem carbon and GHG fluxes over large areas such as counties or climate zones in order to understand the collective impact that land management, including farming practices, is having in the state's efforts towards reaching carbon neutrality at these spatial scales. Advancements are underway to better understand how the implementation of specific agricultural practices at the scale of individual farms contribute to regional and statewide trends even if the focus of the NWL Carbon Inventory is to track changes in ecosystem carbon and GHG fluxes at larger scales. For instance, one contract in progress is developing a model to estimate carbon stocks and GHG emissions from California's croplands under observed conditions updated annually, as well as under future crop management and climate scenarios. The model will rely on remote sensing products to provide input data on prevailing climate conditions as well as on the timing of crop planting and harvesting. It will rely on ground observations to provide the necessary agronomic data on applied irrigation methods and soil amendments which are critical for modeling soil organic carbon and GHG emissions. Future updates to the NWL Carbon Inventory will incorporate the modeling and monitoring results from their current cropland project to help improve understanding of management impacts on soil health, carbon stocks, and GHG emissions across different spatial and temporal scales.

Stakeholder Feedback

Stakeholders suggested improving long-term measurement and monitoring to capture and quantify the benefits of healthy soils practices beyond GHG emissions, such as water holding capacity of soils and improved water infiltration. Others noted that this information may be of interest to ag lenders, who could potentially offer reduced interest rates for producers using climate smart practices if data collection and sharing is included in the agreement. Stakeholders also noted that improved data collection would help build the business case for healthy soils practices and encourage a shift to long-term practice adoption.

HSP Demonstration Grants Soil Water Metric Data Collection

The Sustainable Groundwater Management Act has put a greater focus on on-farm water usage and conservation. In response, in 2023, HSP began requiring that soil water data metrics be collected through the Demonstration Grant projects. These metrics include soil water infiltration, aggregate stability, and soil water holding capacity. The desired goal of these additions is to provide insight into the water savings benefits 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 measurable within the three years of the grant term, and farmers may need to use practices longer 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 much strengthened 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 primarily in agricultural contexts. However, there is vast opportunity to improve soil health in other contexts; for example, urban land managers are also very interested in soil health for wildfire remediation. Additionally, there is increasing recognition that practices developed outside agronomic modalities have immense benefit and should be supported; for example, practices used by indigenous communities for millennia, such as cultural burning. Outlined below are action opportunities CDFA has identified to promote and invest in soil health practices to reach a wider audience.

Belowground Diversity: A New Frontier of Soil Health Metrics

In some cases, there are important impacts of healthy soils practices that should be measured, but that we don't yet have sufficient scientific research to be quantified, especially where benchmark "targets" are missing. In cases like this, the state and our university systems can help advance the science, laying the groundwork for future measurement.

For example, we know that soil biodiversity—the vast community of microorganisms, fungi, invertebrates, and plant roots living belowground—is foundational to the functioning of agricultural and natural ecosystems. Diverse soil life drives key processes such as nutrient cycling, organic matter decomposition, carbon sequestration, and soil structure formation, all of which support crop productivity and resilience. Soil organisms help make nutrients available to plants, suppress pests and diseases, improve water infiltration and retention, and buffer crops against stresses like drought and extreme heat. Research also shows that soils with higher biological diversity tend to be more stable and adaptive over time, making them better able to recover from disturbance and changing climate conditions. While scientists are still working to refine indicators and fully quantify these relationships, there is strong evidence that maintaining and enhancing soil biodiversity is central to soil health, long-term agricultural productivity, and climate-smart food systems.

In Executive Order N-82-20, Governor Newsom called out the importance of soil in hosting over a quarter of the world's biodiversity, the wealth of California's 2,500 soil types, and the contribution of our working lands to the global food supply. He called on state agencies to pursue pathways to inventory, preserve and enhance biodiversity.

To help advance the measurement of soil biodiversity in agricultural lands, in 2022 CDFA convened an expert committee of globally renowned soil scientists. This Belowground Biodiversity Advisory Committee (BBAC) included researchers from several universities including UC Davis, UC ANR, UC Irvine, and UC Merced. In July 2023, the BBAC issued a report, Soil Biodiversity in California Agriculture: Framework and Indicators for Soil Health Assessment, which provides recommendations on measurable indicators for the taxonomic and functional diversity of soil organisms, the ecosystem services they provide, and threats to soil biodiversity. The report also contains examples of how biodiversity indicators can be applied to specific use cases to provide insights for soil health, sustainable and climate-smart agriculture, and biodiversity conservation in California.

10.3.1 Create quantification methodologies for holistic soil health and Traditional Ecological Knowledge practices for expanded eligibility under the Healthy Soils Program.

Goal 1: Improve the Bottom Line for Farmers

HSP incentivizes 29 different conservation management practices, and 11 experimental practices through Demonstration Grants. These practices must sequester carbon and/or reduce GHG emissions to be eligible for inclusion, 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 used by Native American Tribes. For example, CDFA is currently working with CARB to develop quantification methodology for cultural burning. This practice has been shown to boost soil carbon and nitrogen and reduce soil density, improving soil health.[55] Adoption of cultural burning and other traditional practices will expand program accessibility to more groups.

10.4 Promote technical assistance for healthy soil practices to ensure successful implementation.

10.4.1 Utilize technical assistance to help growers understand their soil and crop nutrition requirements and make smart growing decisions regarding fertilizer use.

Goal 1: Improve the Bottom Line for Farmers

Farmers and ranchers may need support to incorporate new practices promoting soil health into their agricultural operations. Technical assistance is often provided by UC Cooperative Extension, Resource Conservation Districts, and consultants. TA providers can build awareness of healthy soils practices, disseminating knowledge about how to implement practices, connecting farmers with resources, and assisting them through adaptive management decisions.
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Establishing trusted connections between farmers and local technical assistance providers can be critical for successful implementation. Technical assistance providers may teach implementation techniques and practices directly, as well as facilitate knowledge sharing among producers to learn from each other. Many technical assistance providers charge a fee for their services, 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.[56] 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.)

CDFA's Fertilizer Research and Education Program (FREP) has funded research projects to develop irrigation and nutrient management decision support tools and calculators that can help farmers predict nutrient contributions from plant and soil amendments to their crops'

nutrition to inform fertilization decisions. These include the Nitrogen and Irrigation Initiative (see section 2.3.3) and funding research supporting resources like an organic amendment calculator to help growers better understand the nitrogen mineralization of different organic amendments typically used in organic and conventional agriculture. FREP's Irrigation and Nitrogen Management Training Program (INMTP) allows growers to self-certify their Irrigation and Nitrogen Management Plan (INMP) Worksheets for their operation(s) in the Central Valley and Ventura County. Also, for CCAs and agricultural professionals interested in preparing for the California Nitrogen Specialty Exam (CA-NSp), FREP has made the modules available online at no cost through the CDFA FREP N Management Training playlist.

10.4.2 Coordinate with technical assistance providers to promote and disseminate information on regionally appropriate crops and agricultural practices.

Goal 1: Improve the Bottom Line for Farmers

State and academic research have been foundational to the success of California agriculture, shaping it into one of the most productive, diverse, and resilient food systems in the world. The University of California system, in particular, has served as the backbone of agricultural innovation through decades of research on crop improvement, pest and disease management, mechanization, and post-harvest quality. Through UC Cooperative Extension (UCCE), this research is translated directly into practice, with advisors working alongside growers to improve irrigation efficiency, nutrient management, pest control, and responses to emerging challenges like droughts, heat waves, and invasive species.

Farmers and ranchers make important decisions every day when managing their agricultural operations, and CDFA and its sister agencies utilize the services of UCCE and its 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 crops that fit local soil and water conditions and 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's Healthy Soils Program is currently working with tribal communities to expand its quantification methodology to include traditional ecological practices.

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 developing an increased supply of compost that will provide vital nutrients to soils and reduce the need for petroleum-based and imported fertilizers. Increasing the availability of high-quality compost will require ensuring compliance with regulations and standards, implementation of best management practices at compost facilities, and ensuring adequate testing and monitoring of the final product. Prioritizing education and outreach regarding collection programs to maximize participation and reduce contamination, as well as installing infrastructure to remove contamination pre- and post-processing are other ways to support the production of clean compost for agricultural use. Additionally, it is important to consider accessibility of compost and similar amendments such that these amendments can be utilized by producers of all farm sizes, this includes considerations for spreading and transport cost and also shared or rentable equipment.

Stakeholder Feedback

Stakeholders emphasized the importance of compost and recommended that it be prioritized as an alternative to synthetic fertilizer. They noted that the benefits of compost carbon sequestration, water retention and infiltration, fertility and soil health, and reduced need for other chemical inputs. However, they also noted compost supply chain challenges, including quality and contamination issues, difficulty scaling up production due to municipal infrastructure capacity, and regulatory barriers to on-farm production. Stakeholders also reiterated the importance of dairy and livestock manure as a compost feedstock. They recommended continuing collaboration between CDFA, CalRecycle, and the State Water Resources Control Board to avoid regulatory conflicts and improve cross-agency data alignment. They also recommended that the state collaborate with the compost industry through a healthy soils roundtable in pursuit of SB 1383 organic waste goals.

Importance of Compost

Compost is a biologically stable soil amendment that can be used to build soil health and provide nutrients to plants.[57] Creating compost requires a managed process of aerobic (oxygen-requiring) microbial decomposition of organic (carbon-based) materials using microorganisms. The organic materials can include food waste, crop byproducts, biomass from forest management, manures, 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, carbon, water, and oxygen to digest materials as they breath, grow, and reproduce.[58] When properly managed, the activity and growth of microbes cause the organic materials to heat up to temperatures beyond 131°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 at various scales, using organic materials left after harvest or food processing, or excess manure supplies.

Finished compost has a number of attributes that make it a highly desirable soil amendment:

- Reduced in 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, workability, reduce soil bulk density, and support soil aggregation and increase soil fertility by increasing soil organic matter;
- Relatively odor-free;
- Stable over a few months in the open, even if exposed to rain;
- High in organic carbon and often 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;
- A much lower emitter of GHGs than most alternative disposal methods for organic wastes; and
- Sequesters carbon and improves soil water holding capacity.

California agriculture is the single largest market for compost statewide and is well-positioned to utilize most of the state's future compost production.[59] It is predominantly used in organic farming operations, although conventional growers are increasingly applying compost.[60] 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, increased plant vigor, and the 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 on-farm manure storage and 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 they were 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. 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.

AB 1981 of 2018 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 compost throughout the state, and to achieve the goal of reducing landfill emissions 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 reducing organic waste disposal, increasing compost creation and use, and incentivizing practices that can build soil carbon and lower greenhouse gas emissions statewide directing the funding for and production of compost and uses for compost.

10.5.1 Develop a statewide compost strategy.

Goal 3: Support Economic Development

CDFA and CalRecycle will collaborate to develop a statewide compost strategy to support the availability of high-quality compost statewide. This collaborative effort will include consultations with other agencies and stakeholders, including the compost industry, wastewater industries, non-governmental entities, agricultural operations, and local jurisdictions. The strategy will include but not be limited to exploring the following:

- How agencies can improve their existing processes, including interagency coordination and between levels of government to improve outcomes.
- Streamlining permitting and the creation of a unified simplified regulatory guidance manual for safe on-farm composting.
- The potential for investments to catalyze the affordability, sorting, or treatment of soil amendments to make them attractive for on-farm use.
- How outside sources of financing could be invited in or channeled; e.g., voluntary carbon markets.
- Identifying investments that would solve for other local issues and opportunities when funds become available, setting priorities.
- How transportation costs could be offset where a compelling public good exists.
- How to supply greater clarity for farmers as consumers with labeling and quality reporting and creating feedback loops with the composting industry.
- How activities could be tracked efficiently.
- How to provide services such as webinars for sharing information amongst stakeholders about climate-smart and healthy soils practices tools and data related to the availability of compost, dairy-sourced compost, mulch, anaerobic digestate, biochar, and other recycled biomass products that can be used in agriculture.

10.5.2 Support local jurisdictions' investment in organics diversion infrastructure including food and green waste processing.

Goal 3: Support Economic Development

To meet SB 1383 waste diversion goals, counties and local jurisdictions are investing in planning and infrastructure to produce compost on a large scale.[61] CalRecycle provides overarching guidance and permitting for compostable material handling facilities and operations, including type and amount tiers that have specific regulations.[62] Additional permitting for compost facilities comes at the local level through regional water boards and air districts. 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 providing training materials, tools, and guidance documents for local jurisdictions to facilitate this process.

10.5.3 Provide guidance for best practices in production, selection, and application of safe, fully-finished compost.

Goal 1: Improve the Bottom Line for Farmers

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 production and application meet state soil amendment quality standards and food safety standards. Integrating multiple waste streams, especially co-mingling of feedstock from sources such as animal manure and post-consumer household food waste, can potentially impact the risk of food-borne illnesses, especially when intended for application in production of fresh produce such as fruits, vegetables and nuts that are intended for farm to table consumption (i.e., consumed raw). This risk may be present in situations where non-licensed/excluded entities produce compost (such as farms producing less than a specified volume of compost), or the composting entity may have limited knowledge, technical assistance resources or oversight regarding implementation of Processes to Further Reduce Pathogens (PFRPs) in production of fully-finished compost produced. There is a need for technical assistance for growers related to production of fully-finished, safe compost and its safe handling, storage and application. This assistance should align with the educational, outreach and technical assistance efforts that support the soil health and climate change mitigation benefits of compost use, thus maximizing the multiple benefits that can be achieved through this practice, including safe food production.

The state is working on standards for both compost quality assurance and proper selection and application guidance; however, continued collaboration between technical assistance and outreach is needed. CalRecycle sets standards for, and permits, compost production facilities to ensure potential contaminants such as weeds, pests, pathogens, and other contaminants are reduced below limits. CalRecycle also 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 entities are currently working to help ensure, and incentivize, quality compost is used on agricultural land, and other organizations such as RCDs and UC ANR can help provide education to farmers and ranchers to make the best choices for their soils and crops and to provide guidance about compost quality. Lastly, CDFA's Food Safety Modernization Act Technical Assistance Program is helping small scale farmers meet food safety standards on their farms.

Stakeholder Feedback

Stakeholders recommend that the state provide technical guidance for farmers to help them source organic-certified, high-quality materials (such as those registered through CDFA's Organic Input Material Program or certified through the US Compost Council's Seal of Testing Assurance (STA)). They also noted the need for training for technical assistance providers to understand how to select compost and verify quality. They recommended that CalRecycle publish a quality control guide for compost producers.

10.5.4 Continue state agency coordination to clarify on-farm composting and food safety regulations.

Goal 1: Improve the Bottom Line for Farmers

Currently, state-permitting for on-farm compost production limits 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. Increasing these amounts can require intensive permitting processes and coordination between local Air Districts, LEAs, and Water Boards which can be a deterrent to farmers who would otherwise be interested. In an effort to bolster local bioeconomies and improve efficiency of on-farm waste management, SB 279 (McNerney, 2025) eliminates the maximum square-foot condition, updates the total amount of feedstock and compost allowed onsite at any one time, increases the limit of compost that can be given away or sold annually, and increases the limit that can be produced resulting from a large-scale biomass management event at an agricultural facility.

Dairy and Livestock Manure as a Compost Feedstock

There is potential for dairy manure to help meet regional demand for compost and replace some synthetic fertilizer use on cropland, reducing cropland nitrous oxide emissions and nitrate leaching or runoff. Dairy manure is an abundant and nutrient rich resource in California. When composted, dairy manure's nutrients are stabilized, significantly reducing the risk of nitrate leaching into groundwater and surface water, aiding in meeting water quality goals. Dairies are uniquely situated to help California meet the growing demand for compost by converting a waste challenge into an environmental and economic benefit, and expanding compost availability regionally and across the state to contribute to the state's soil health and water quality goals. However, despite recent progress updating regulatory requirements to increase dairy composting, there are still challenges associated with using compost from dairies including permit streamlining.

10.5.5 Identify compost and digestate research gaps and support research to address gaps.

Goal 4: Provide Health and Environmental Benefits

There are significant gaps in research related to compost that should be identified and addressed with broad state agency coordination. More research is needed in a variety of topic areas to further assess composting infrastructure development, future compost availability to agriculture that takes into account available feedstocks, transportation costs (both in terms of dollars and greenhouse gas emissions), and regional demand. Below are examples of research topics that may be explored:

1. Proximity and sources of feedstocks to end markets. More than half of the population of California lives in southern counties that contain about 10 percent of the state's cropland and even less of its grazing land. If the valuable greenand food-wastes from these counties are to be used for agriculture, it may become necessary to support the transportation of compost made from these areas to counties located farther away in order to better optimize and distribute compost throughout the state. Overall, there is more to study in the optimization of compost production with respect to the spatial distribution of feedstock sources, their qualities, and their end use points.
2. Remediation of salinity in certain organic amendments and food waste processed in wastewater treatment plants, the use of biosolids, and recapture of organics from digester slurries.
3. Research aimed at regulatory improvements and efficiencies.
4. Comparison of composting GHG, VOC, and ammonia emissions with likely alternative fates.
5. Effects of plastics on compost quality and marketability, including how plastics in compost impact nutrient availability, soil microbiology, and plant growth.
6. Physical contamination from feedstocks containing food waste and mixed organics. With the increase of food waste collection, ongoing research on collection programs, including how education and outreach impact contamination and compost, is needed.
7. Compost application potential and benefits. The benefits of compost are widely understood; however, more research is needed to understand the long-term carbon sequestration benefits and factors influencing GHG emissions from compost applications.

10.5.6 Support soil health and circularity for green school yards.

Goal 4: Provide Health and Environmental Benefits

Schools and universities generate about 562,442 tons of waste each year in California. Almost half of the school waste is comprised of organic materials like paper, cardboard, and uneaten cafeteria food. Building the state's Healthy Soils and circular bioeconomy work, CalRecycle will continue to provide support and education to create green school yards that utilize circular systems, including making and using compost in gardens and growing food.

10.5.7 Partner with California Native American Tribes to create circular systems.

Goal 4: Provide Health and Environmental Benefits

CalRecycle recognizes the critical role and commitment of California Native American tribes (Tribes) in advancing climate solutions. In 2025, CalRecycle published a Tribal Composting Needs Assessment to understand the priorities and resources needed by Tribes for developing and operating composting facilities to divert materials from landfills and to help foster climate resilience. CalRecycle will also continue partnering with California Native American tribes to create circular systems with community composting sites and utilizing compost to grow food.

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.[63] Despite the number and variety of inputs urban soils receive, they can still accommodate high levels of biodiversity. For example, 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.[64] 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.

Case Study: Cover Cropping and Compost Application Have Direct and Indirect Benefits on Soil Health

Funded Organization: Gemperle Orchards

Funding Program: Healthy Soils Program Incentives Grants

Award Year: 2022 (grant period from 9/1/2022 to 2/21/2025)

Project Implementation County: Merced

Top: Gemperle Orchard after establishing the cover crop (year 1). Bottom: Year 3 of cover cropping and compost application.

Christine Gemperle is a second-generation almond farmer who bought Gemperle Orchard in 1998 with her brother and business partner. Using her educational background in biological science, she manages the land with an appreciation for the rich (and sometimes unexpected) direct and indirect benefits afforded by nature when stewards of the land support the local environment. They utilized whole orchard recycling to revitalize the soil after the 2021 drought, as well as composting and cover cropping that CDFA's Healthy Soil Program grant allowed them to do. This has had positive effects on the types of animals present on the plot; there has been an increase in the number of beneficial predator insects and birds that will likely help with pest control once harvesting season arrives.

Christine has found that these climate smart practices save her money and time in the long run. Through cover cropping, she has needed to use less diesel for her tractor, has spent less time using it overall, and has noticed less wear-and-tear on its tire belts. Allowing the cover crop to reseed itself has allowed them to create a seed bank so that they do not need to buy seeds every year. One striking benefit is an increase in water use efficiency. Covering the bare land with vegetation cools it down such that the irrigated water does not evaporate as quickly and acts like a sponge in heavy rain events, leading to roughly 30 percent water savings. Where she has presented her insights to a wide range of farmers, they have shown keen interest in adopting these practices.

Christine Gemperle with her brother Erich.

*"A **healthy agricultural system** starts from the **ground up**... By creating the **right conditions**, we have been able to enjoy many **surprising benefits**; it might bring in new variables in the environment, but this is not necessarily a bad thing. [It was clear, though,] how daunting it would be to set out on such a massive undertaking without **CDFA's grant funding**, but it was **comforting** to see the project idea being properly implemented and that it showed **impressive initial results** in the young orchard, such that they are **motivated** to keep these climate smart practices **underway in the future**."*

– Christine Gemperle

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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.	4: Provide Health and Environmental Benefits	CDFA, CalEPA, DWR, DSC, Delta Conservancy	Healthy Soils Initiative, CalRecycle's Compost and Mulch Use Toolbox
10.1.2 Facilitate the adoption of climate-smart and healthy soils practices by farmers, ranchers, and private landowners.	2. Reduce Greenhouse Gas Emissions	CDFA, CARB, CARCD, USDA	Healthy Soils Program (HSP), 2022 Scoping Plan for Achieving Carbon Neutrality, Healthy Soils Quantification Methodology, COMET-Planner Tool, UC Community Education Specialists, Climate Action Planning resource guide, County Specific Action Guides - San Mateo, San Diego, Yolo County, Marin County; Ag Burn Alternative Grant Program, Regional Carbon Farming Hubs, Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program
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 indicators to measure and monitor the impact of healthy soils practices over time.	4: Provide Health and Environmental Benefits	CDFA	California Natural and Working Lands Carbon Inventory
10.3 Expand inclusivity of soil health programs.			
10.3.1 Create quantification methodologies for holistic soil health practices and Traditional Ecological Knowledge practices for expanded eligible practices under the Healthy Soils Program.	1: Improve Bottom Line for Farmers	CDFA	
10.4 Promote technical assistance for healthy soil practices to ensure successful implementation.			

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
10.4.1 Utilize technical assistance to help growers understand their soil and crop nutrition requirements and make smart growing decisions regarding fertilizer use.	1: Improve Bottom Line for Farmers	CDFA	Certified Crop Advisors, Pest Control Advisors, Fertilizer Research and Education Program
10.4.2 Coordinate with technical assistance providers to promote and disseminate information on regionally appropriate crops and agricultural practices.	1: Improve Bottom Line for Farmers	CDFA	Delta Protection Commission, Delta Conservancy, Belowground Biodiversity Advisory Committee
10.5 Ensure the availability of high-quality compost for agricultural operations statewide.			
10.5.1 Develop a Statewide Compost Strategy	3: Support Economic Development	CalRecycle	
10.5.2 Support local jurisdictions' investment in organics diversion infrastructure including food and green waste processing.	3: Support Economic Development	CalRecycle	CalRecycle Green Waste Resources
10.5.3 Provide guidance for best practices in production, selection, and application of safe, fully-finished compost.	1: Improve Bottom Line for Farmers	CalRecycle	SWIS Website, Map of Composters, US Compost Council's Seal of Testing Assurance, Fertilizing Materials Inspection Program, Organic Input Material Program
10.5.4 Continue state agency coordination to clarify on-farm composting and food safety regulations.	1: Improve Bottom Line for Farmers	CalRecycle, CDFA, EPA	CA Bill SB279
10.5.5 Identify compost and digestate research gaps and support research to address gaps.	4: Provide Health and Environmental Benefits	OPC, DTSC, USDA, EPA	
10.5.6 Support soil health and circularity for green school yards.	4: Provide Health and Environmental Benefits	CalRecycle	
10.5.7 Partner with California Native American Tribes to create circular systems.	4: Provide Health and Environmental Benefits	CalRecycle	

11 Improve Ranching Sustainability & Rangeland Management

Key Objective: Utilize climate-smart practices to promote resilient ranching and rangeland management.

Livestock grazing is one of the most widespread agricultural land uses in California, encompassing about 32 million acres of rangeland, pasture, forested lands, and perennial croplands that support cattle, sheep, goats, and other livestock. However, the sector faces growing threats from drought, wildfires, land-use change, and climate stress. As grazed areas decline with land use change and climate pressures, increasing the adoption of beneficial grazing and rangeland management practices is critical for both a sustainable ranching industry and climate-resilient and thriving landscapes. Research shows that well-managed grazing systems, utilizing such practices as regenerative grazing, adaptive multi-paddock grazing, and silvopasture can help maintain or improve soil carbon, forage productivity, biodiversity, and erosion control, while providing improved forge and shade for animals.

This chapter explores climate-smart grazing and rangeland management strategies that sustain ranching livelihoods, enhance ecosystem health, and contribute to California's climate and methane reduction goals.

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.[65]

"Livestock" may refer to cattle, sheep, goats, llamas, alpacas, and other species. Land suitable for grazing that is uncultivated (not tilled, irrigated, or fertilized) and dominated by grasses and shrubs is referred to as rangeland.[66] In California, there are a number of landscape types that support grazing beyond grasslands and shrublands (i.e., rangeland), including irrigated pasture, forested lands, and perennial croplands.

As of 2020, California's landscape was home to roughly 1.8 million beef cattle, with cattle grazing happening in almost every county in California. Eighty percent of herds consist of under 200 cows.[67] The state is also the second in the nation for sheep and lamb production, with around 600,000 animals.[68] Drought, wildfires, land use change, and workforce challenges threaten the ranching industry, driving the urgency for climate resilient and multi-purpose grazing and rangeland management in California.[69]

At the same time, methane emissions from non-dairy livestock constitute approximately 11 percent of the state's methane emissions.[70] As discussed earlier in this strategy, California has set a target to reduce methane emissions from dairy and livestock sectors by 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, topography, organisms, and precipitation patterns play a primary role in establishing baseline soil conditions across all lands, including ecosystems used for grazing in California.[71] Research has shown that the presence of grazing animals can positively affect soil carbon in California soils with higher clay content, but more work is still needed to understand how grazing livestock can be managed to increase soil carbon in other specific circumstances.[72] 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.[73] Managed grazing can also promote the growth of healthy forage, positively impact species composition and biodiversity, and minimize erosion.[74] 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, and through increased soil fauna activity, while also providing shade for grazing animals to prevent heat stress (increasingly important as temperatures increase due to climate change).[75] Managed livestock grazing, in conjunction with other climate-smart agriculture practices, is one method to promote healthy lands, promote durable carbon in the soil, and build resilience to climate change.

Chapter 11: Improve Ranching Sustainability & Rangeland Management

Strategies and Actions

Climate-smart ranching offers a multitude of benefits—including better soil health, fuel load management, maintaining open space, and much more. California is taking a multi-pronged approach to reducing emissions from livestock while bolstering the health of rangelands and sequestering carbon.

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.[76] Working with certified rangeland managers, registered professional foresters, and other professionals to create detailed management plans that include goals, measurable outcomes, and how to address environmental considerations such as riparian areas, soil health, water quality, and sensitive species can limit potential harms and achieve ranching and environmental health related goals. In these plans, ranchers can utilize several management practices such as strategically placed fencing, nutritional supplements and water sources, as well as herding to create positive relationships between riparian health and livestock land use.[77]

Stakeholder Feedback

Stakeholders recommended the state expand its support for regenerative grazing through funding, technical assistance, and partnerships with lenders, and encourage the integration of ecological goals into lease agreements.

Wildfire Mitigation

Proper livestock grazing, in conjunction with other land management practices, can play a cost-effective role in creating a more resilient ecosystem.[78] Important goals of managed grazing are fuel reduction for wildfire mitigation and the creation of fuel breaks. Livestock can be used to reduce fire fuels by selectively removing vegetation as the animals graze and incorporating 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.[79]

The selection of appropriate livestock for grazing is dependent on the land manager's goals and the type of forage available.[80] Cows with calves tend to prefer grass species and hills with gentle slopes (under 20 percent grades) to feed 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 inch) woody material, cattle are more effective at removing grassy fuel. Livestock do not consume all plants equally, which can lead to a shift in plant community species composition in both desirable and undesirable directions. This reinforces the need to manage rangelands and grazing animals intentionally to achieve specific land management objectives.[81] In areas where grazing has been removed, encroachment of shrub cover often increases, which can significantly increase fire risks.[82]

11.1.1 Facilitate grazing on public lands for ecological health and fuel load reduction.

Goal 4: Provide Health and Environmental Benefits

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, which was updated in 2025 (2025 Update) with information about new technologies and research. This document outlines how the intentional use of livestock to remove, rearrange, or convert vegetation in wildlands, including rangelands, can 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. Signed in 2024, SB 675 (Limon, 2024) required the RMAC to develop guidance for local or regional prescribed grazing plans—a draft was approved by the RMAC and Board of Forestry and Fire Protection in December 2025 for anticipated publication in early 2026.

CDFW leases state lands for grazing to help with vegetation management. This process provides ranchers with access to state-owned land for livestock grazing while also helping to maintain ecosystem health and reduce catastrophic wildfire risk. Additionally, the Board of Forestry and Fire Protection's California Vegetation

Chapter 11: Improve Ranching Sustainability & Rangeland Management

Treatment Program utilizes prescribed herbivory, which is the targeted grazing by livestock to reduce fire risk. 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.[83]

CDFA's 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 non-pasture dairy or livestock operations to pasture-based management and incentivizes dairy and ranch managers to increase the amount of time livestock spend at pasture in existing pasture operations. 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 wildfires; it also reduces methane production in manure by creating more aerobic conditions.

Stakeholder Feedback

Stakeholders commented that the state could better facilitate and utilize grazing on public lands for ecological health and wildfire fuel reduction; they requested that CDFA work with State Parks, the State Lands Commission, and local governments to collaborate with these entities to expand grazing opportunities. They recommend the state work to educate the public and state agencies on ecological benefits of managed grazing, and collect data on the soil carbon, biodiversity, and wildfire risk reduction benefits of grazing. They note that these opportunities support small and mid-sized producers who utilize sustainable and regenerative practices.

11.1.2 Increase adoption of climate-smart agricultural practices on rangeland.

Goal 2: Reduce Greenhouse Gas Emissions

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 integration of trees with forage crops in pastures, can provide food and shelter for livestock as well as windbreaks that help prevent erosion and build habitat that supports 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.[84] Technical assistance and the provision of decision-making tools can improve practice implementation and increase 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 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.[85]

Stakeholder Feedback

Stakeholders noted that technical assistance is critical for increasing the adoption of climate-smart practices, and more providers are needed to assist with grazing planning (utilizing conservation grazing; evaluating the duration and movement of livestock), applying compost, seeding perennials, brush cutting and crushing, prescribed burns, inoculants, and thinning of undesirable species through conservation grazing.

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.[86] Grassland landscapes, which offer many ecosystem services, are disturbance-dependent and require grazing or fire to persist. 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 with California's 30 x 30 Initiative.

Goal 4: Provide Health and Environmental Benefits

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 30x30 highlights ten 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 areas where non-native species dominate the landscape.[87] The Rangeland, Grazing Land and Grassland Protection Program at the California Wildlife Conservation Board (WCB) is designed to promote the 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 Chapter 6). Elevating the role of rangelands in boosting biodiversity can help protect rangelands, build awareness of conservation measures, and build support for these actions through various state and partner programs.

Stakeholder Feedback

Stakeholders recommend that the state invest in grazing science and monitoring that can improve our understanding of how adaptive grazing practices benefit native species, control invasive plants, and enhance soil health.

11.2.2 Improve riparian areas in rangelands for improved water filtration, flood protection, and habitat connectivity.

Goal 4: Provide Health and Environmental Benefits

Riparian areas on California's rangeland are critical; they provide habitat for wildlife, filter pollutants, control erosion by maintaining vegetative cover and reducing runoff and sedimentation and sequester carbon.

The Wildlife Conservation Board 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 re-establish floodplain connectivity, repair riparian vegetation,

install fencing to manage livestock, and restore streams. 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.

Ensuring sustainable water sources 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 damage. 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.[88] Stock ponds, or man-made ponds designed for human and animal use, can also promote groundwater recharge and be used by CalFire for firefighting. These ponds are regulated by the State Water Resources Control Board, and ranchers must comply with all regulations pertaining to their use.[89] Programs that assist with regulatory compliance and proper implementation of stock ponds can help protect riparian areas and enable ranchers to better implement a prescribed grazing plan.

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 it into amino acids and fatty acids, which are essential for the production of milk. As the microbes decompose plant material in the rumen, methane is expelled by the animal through burping. Manure can also produce methane as it decomposes, and the amount of methane produced is strongly influenced by how the manure is managed. Manure from animals grazing in pastures is considered "dry" management and produces little to no methane *(for information on manure management in dairy systems, see chapter 12 on Dairy Farming Sustainability)*.[90]

11.3.1 Research and promote novel enteric methane mitigating practices for grazing livestock.

Goal 2: Reduce Greenhouse Gas Emissions

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 enteric methane output is centralized, grazing animals are dispersed across a landscape. This makes addressing methane from enteric pathways a challenge. This is because enteric emissions solutions that work well in dairy, such as feed additives, are harder to implement when the animals are spread across great distances and they are eating vegetation rather than being fed a specific feed mix.

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 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.[91]

Stakeholder Feedback

Stakeholders note that genetic improvements made to livestock must not come at the expense of health attributes, including how animals fit for climate and terrain where they live and their ability for successful natural births, instinct to nurse, and protect calves.

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.[92] 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.[93] 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.[94] For all of these strategies, continued testing and research is needed to ensure the product is safe and effective for the animal, and results in safe human food products (meat and milk) derived from the animals. CDFA defers to the United States Food and Drug Administration (U.S. FDA) for review of safety and efficacy, and legal pre-market approval of all feed additives and animal drugs.

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, Increase Dairy Farming Sustainability.)

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Initiatives
11.1 Promote multi-benefit rangeland management.			
11.1.1 Facilitate grazing on public lands for ecological health and fuel load reduction.	4: Provide Health and Environmental Benefits	CalFIRE, CDFW	Board of Forestry and Fire Protection, Range Management Advisory Committee (RMAC), Prescribed Herbivory for Vegetation Treatment Projects, Livestock Grazing Management Resources, California Vegetation Treatment Program, Alternative Manure Management Program
11.1.2 Increase adoption of climate-smart agricultural practices on rangeland.	2: Reduce Greenhouse Gas Emissions	CDFA	Healthy Soils Program
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 California's 30x30 initiative.	4: Provide Health and Environmental Benefits	CNRA, WCB	Pathways to 30x30, California Rangeland, Grazing Land and Grassland Protection Program
11.2.2 Improve riparian areas in rangelands for improved water filtration, flood protection, and habitat connectivity.	4: Provide Health and Environmental Benefits	WCB, DOC, SWRCB	California Riparian Habitat Conservation Program, Working Lands and Riparian Corridors Program
11.3 Reduce enteric methane from grazing livestock.			
11.3.1 Research and promote novel enteric methane mitigating practices for grazing livestock.	2: Reduce Greenhouse Gas Emissions	CDFA	Clarity and Leadership for Environmental Awareness and Research at UC Davis, Spark Climate Solutions, State of the Science Summit: Reducing Methane from Animal Agriculture, Office of Agricultural Resilience and Sustainability (OARS) Research Funding, Livestock Enteric Methane Emission Reduction Research Program

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.

California's dairy industry is a cornerstone of the state's agricultural economy and food security. However, dairies account for roughly 43 percent of the state's methane emissions and can contribute to groundwater nitrogen loading, making methane and nutrient management both a challenge and an opportunity for climate mitigation and environmental protection. At the same time, the sector is undergoing consolidation, highlighting the need for solutions that improve air and water quality, protect communities, and support the long-term resilience of dairies of all sizes. To address these impacts while supporting milk production in the state, California has set ambitious climate targets under SB 1383 to reduce methane emissions from dairy and livestock operations 40 percent below 2013 levels by 2030, supported by strategies focused on manure management, waste diversion, and energy generation.

This chapter explores strategies to reduce greenhouse gas emissions and increase the sustainability of dairy farming by increasing knowledge and implementation of methane reduction technologies, carrying out research to introduce new methods and solutions, and collaborating across agencies to open additional or previously untapped revenue streams.

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.[95]

California is taking steps to curb the environmental impacts of the dairy and ranching, while also promoting sustainability pathways for these industries. Senate Bill 1383 (Lara, 2016) established statewide reduction targets for short lived climate pollutants, including to reduce methane emissions 40 percent below 2013 levels by 2030 in the dairy and livestock sectors. To meet its ambitious climate goals, the state has developed a number of strategies for reducing greenhouse gas emissions each year through organic waste diversion, manure management, and energy creation.

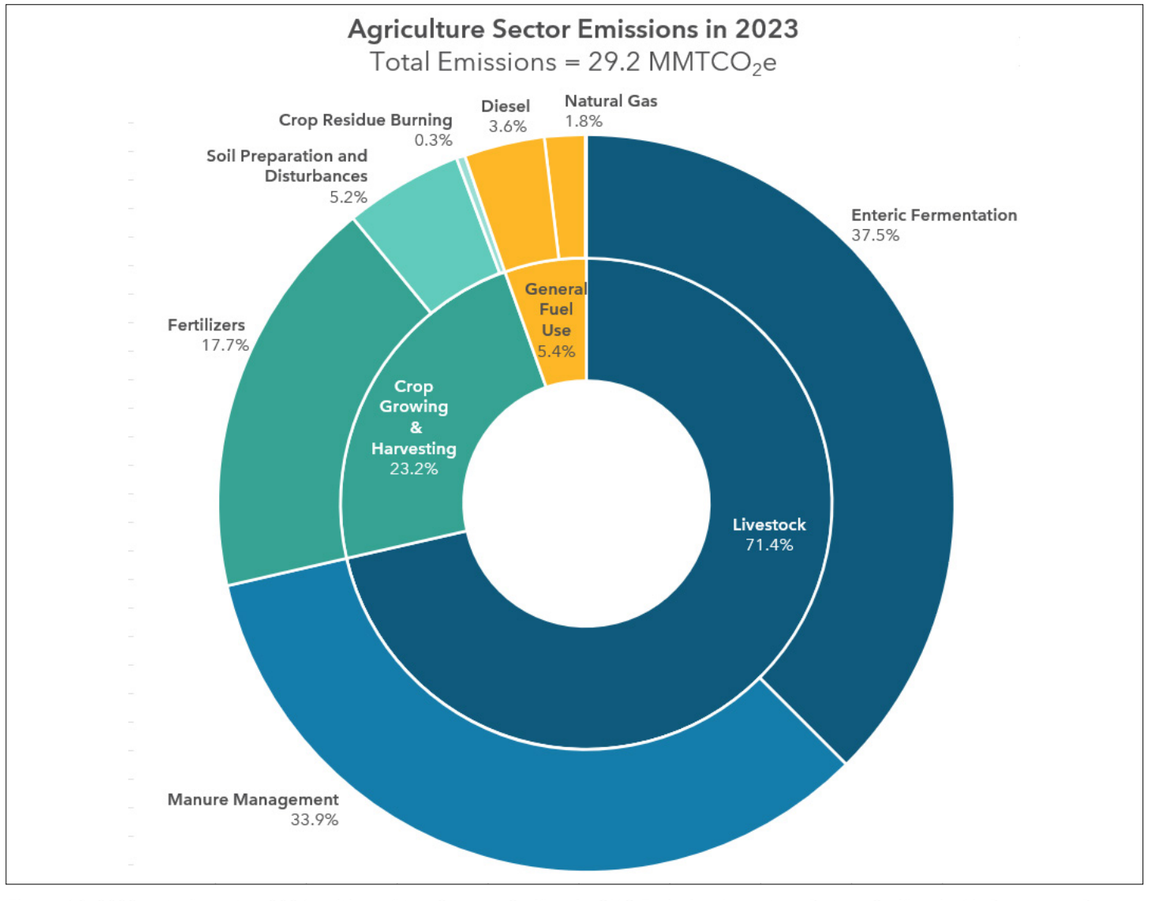

Figure 16: 2023 data from the 2024 edition of the Current California GHG Emission Inventory Data | California Air Resources Board

Greenhouse Gas Emission Reductions and Water Quality

For California dairies, methane reduction presents as one of the greatest challenges but also 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.[96] Ruminants like cows produce methane through their digestive process, known as enteric methane. Manure also produces methane if is decomposes 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.[97] Dairies and ranches are responsible for about 70 percent (5.7 percent of the state's total emissions) of greenhouse gas emissions attributable to agriculture and represent 43 percent of the state's methane emission budget.[98]

Animal manure (including from dairies) contributes to 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 N_2O emissions, but is also the main source of nitrogen loading, causing nitrate contamination of groundwater drinking sources in many agricultural areas.[99]

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 lower production costs per unit of milk, are better able to survive.[100] 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.[101] The number of dairy farms in California has dropped from almost 1,500 in 2013 to 1,074 in 2022, while the average dairy herd size has increased by more than 200 mature cows per farm in the same period.[102]

Air Quality

As many of our state's leading counties for dairy production are also among the worst in air quality nationwide (i.e., high ozone concentration and fine particulate matter), there is concern with the potential environmental impact of dairies, in particular to air quality.[103] Building resilience within the dairy sector means not only creating sustainable operations across a range of herd sizes, but also incentivization of practices that minimize or mitigate emission of air criteria pollutants and contribute to building stronger economies and healthier communities.

Strategies and Actions

Strategies to reduce greenhouse gas 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 research to introduce new methods and solutions, and collaborating across agencies to open additional or previously untapped 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 implement and update 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: Reduce Greenhouse Gas Emissions

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 offer solutions to dairy and livestock operations looking to reduce methane emissions, among other co-benefits, such as the production of compost and better nutrient management. Eligible practices for AMMP funding are those for which there are current and validated 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 prior to their entry into wet or anaerobic conditions, and conversion of a flush-based system to a scrape system. 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.

Stakeholder Feedback

Stakeholders recommend the state conduct a cost analysis for various methane reduction strategies to help diaries understand the potential costs of transitioning to a lower-methane system. They note that this could be particularly helpful for increasing adoption among small and medium-sized dairies.

Stakeholders noted the attrition of small and medium-sized dairies in California and recommended that the state expand programming specifically for small-scale and pasture-based diaries, ensuring focused technical assistance and funding for smaller operations.

As of August 2025, AMMP has funded 195 incentive and demonstration projects for over $123 million since the program was established in 2017. While match funding is not required for AMMP, producers have committed around $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. The California Dairy Research Foundation (CDRF), in collaboration with CDFA and several other organizations, was awarded $85 million in funding by the USDA (initially through the Partnerships for Climate-Smart Commodities Program, now through the Advancing Markets for Producers program), leveraging state funds to match. Over five years (2023-2028), the project 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's funding, 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, and includes advanced solid-liquid separation through centrifuge or assisted by flocculants and/or bead filters, vermifiltration, and solid separation through a weeping wall. The Dairy Plus Program also funds post-processing secondary 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 aims to award $75 million in federal incentive funds to dairy operators interested in pursuing a more impactful and comprehensive project than what could be supported through CDFA's AMMP or DDRDP funding alone, addressing both manure methane emission and nutrient surplus.

As of August of 2025, Dairy Plus Program has funded 14 incentive projects for over $16.75 million since the program was established in 2023. These projects count with $10 million

in matching funds committed directly by producers and another $8.4 million from the State of California through eligible AMMP and DDRDP grant funds. These advanced manure management projects, together with their accompanying AMMP and DDRDP, are estimated to reduce over 783,000 $MTCO_2e$ over their lifetime (5 years for AMMP or 10 years for DDRDP related projects) or 107,000 $MTCO_2e$/year mostly by reducing methane emissions. Another 23 awards for over $26.8 million were announced in December of 2025, while another $31 million is expected to be awarded in 2026.

Technical Assistance for Dairy Farmers

CDFA provides technical assistance for several of its climate-smart agriculture programs including AMMP through its Technical Assistance grant program and partnership with UC ANR. Technical assistance providers can offer outreach and education, application assistance, and 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 are 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: Reduce Greenhouse Gas Emissions

The most effective technology for reducing methane emissions on dairy farms is the anaerobic digester. Dairy digesters break down manure, in a contained environment without oxygen, to produce digestate and methane biogas. Digesters trap 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 ($MTCO_2e$) basis compared to other California Climate Investment (CCI) funded programs to date.[104]

As of November 2025, DDRDP has awarded $229.4 million for 142 incentive projects, of which 132 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 $525 million in matching funds, demonstrating their commitment to dedicate resources to 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 and economic, environmental, and financial benefits to local communities and economies.[105] The program requires that all funded projects meet high standards for air quality and water quality protection, including measures to prevent lagoon seepage and nitrate leaching.

Windrows for composting separated manure solids at a 2019 AMMP project

Compost Bedded Pack Barn installed for a 2017 AMMP project.

Dairy Digester Project, 2020, Maas project

2019 AMMP recipient's new manure solid-liquid separator

4K Dairy, 2018 DDRDP Recipient

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.[108] 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 uses for manure handling and transportation and cleaning out manure storage ponds, improved efficiency in water use and recycling, and improved nutrient management for the facility (including the ability to export nutrients and to better control nutrient application to fields).

Case Study: Technology Fuels Sustainability On and Off the Dairy Operations

Project Funding Program: Dairy Digester Research & Development Program

Awarded Organization: Maas Energy Works, LLC

Award Year: 2018

Project Implementation County: Tulare

Aerial views of lagoon with liner.

Maas Energy Works, LLC is a company that plans, owns, and operates facilities in partnership with dairy families to transform dairy manure into clean energy and has developed more than 85 dairy digesters across nine states. The Lakeside dairy digester cluster in the Central Valley includes Decade Centralized Digester that pools biogas from two dairies through a private, low-pressure pipeline to the cluster's central hub, where it is transformed into renewable natural gas (RNG).

CDFA's Dairy Digester Research & Development Program (DDRDP) assists California's farmers and ranchers in installing anaerobic dairy digesters to ensure that the industry continues to be at the forefront of improving dairy sustainability. Maas Energy Works' DDRDP project used an existing, fully permitted, covered and double-lined lagoon, which facilitates RNG deployment and reduces costs. This project is 100 percent farmer-owned, bolstering local ownership and long-term sustainability. The dairy digester expands Decade Centralized Digesters' portfolio of operational dairy digesters, reinforces their leadership in RNG development, and generates revenue through project management, operations, and carbon credit services to support California's clean energy goals.

Maas Energy Works highlights that this innovative, yet replicable, infrastructure helps meet Senate Bill (SB) 1383 goals and Low Carbon Fuel Standard (LCFS) targets, supports the surrounding community by reducing greenhouse gas (GHG) emissions, air pollutants, and odors, as well as supports local job creation through construction and ongoing maintenance operations. The excess RNG that Decade Centralized Digester produces either fuels public trucks at an on-site compressed natural gas (CNG) fueling station or is cleaned and injected into the utility pipeline for delivery to other CNG fueling stations around the Central Valley and the state.

*"Maas Energy Works saw this Decade Centralized Digester project as a **high-impact opportunity** to demonstrate the **viability of large-scale, farmer-owned renewable energy projects.**" "Thanks to subsidies from CDFA, we [Decade Centralized Digester] were able to bring this project to life. It has allowed us to **diversify our operations**—expanding beyond milk production to also generate renewable methane gas. This initiative not only supports **sustainability** but also provides a valuable **new revenue stream** for our business. Each part of this operation contributes towards the general recycling process on a dairy…. In addition to the **mitigation of GHG emissions, and job creation**, this project also [helps improve] manure management, reducing odors and runoff risks. Additionally, the use of cleaner fuels in local transportation fleets contributes to **improved regional air quality.**"*

- Maas Energy Works and Decade Centralized Digester

12.2 Collaborate with sister agencies and other partners to carry out additional research to bring on new methane reduction methods.

Reducing enteric methane emissions from livestock is a critical climate priority that requires sustained and targeted research, given methane's high global warming potential and the biological complexity of ruminant digestion. Enteric methane arises from microbial processes in the rumen, meaning effective mitigation depends on advances in animal nutrition, genetics, microbiome science, and management practices that can lower emissions without compromising animal health, productivity, or farm viability.

Research is needed to develop and validate feed additives, alternative forages, breeding strategies, and precision management tools that deliver durable, scalable reductions across diverse production systems and regions. Equally important is research that addresses measurement, monitoring, and verification, so that methane reductions can be accurately quantified and credited in climate programs. Without a strong research foundation, efforts to reduce enteric methane risk being fragmented, inequitable, or short-lived; with it, the livestock sector can make meaningful, cost-effective contributions to near-term climate mitigation while supporting food security and rural livelihoods. CDFA is working with other state agencies and partners to develop new and innovative strategies for reducing enteric methane and novel methane.

Stakeholder Feedback

Stakeholders would like to see the state support ongoing research to support the inclusion of new methane strategies in existing programs like AMMP, especially strategies with co-benefits that help achieve other state goals besides methane (e.g., AB 1757 targets for healthy soils practices and organic conversion, Irrigated Lands Regulatory Program water quality goals) and that would be available for a wide variety of dairies, such as the inclusion of biochar in manure compost piles and prescribed grazing for enteric emissions reductions.

Stakeholders noted that there are co-benefits from the AMMP program, including compost production, that are critical to meeting other state goals, such as the need to reduce the import and use of fertilizers derived from fossil fuels. They recommend the state convene an interagency task force to align AMMP and related practices with methane, water quality, and soil health goals, and model the compost availability impacts of the program.

12.2.1 Develop methodologies and program processes for new enteric methane reduction programs.

Goal 2: Reduce Greenhouse Gas Emissions

In 2023, the state budget allocated an initial $2 million to CDFA to develop a framework for producers to adopt enteric methane-reducing strategies. In 2024, CDFA conducted focus groups with a variety of stakeholders on how to incentivize enteric reductions and rigorously quantify and track them. Based on this work, CDFA produced a report summarizing discussions, the Enteric Methane Focus Group Summary Report which would inform any future program to reduce enteric emissions.

12.2.2 Support research dedicated to enteric emissions reduction strategies.

Goal 2: Reduce Greenhouse Gas Emissions

CDFA has funded significant research intended to fill gaps in what is known about various methane reduction solutions. A primary area of focus is enteric emission reduction strategies—mitigating the methane produced during ruminant digestive processes that are expelled through burps. Enteric emissions from dairies represent 20 percent of the state's methane emissions, but solutions are only recently emerging.

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.

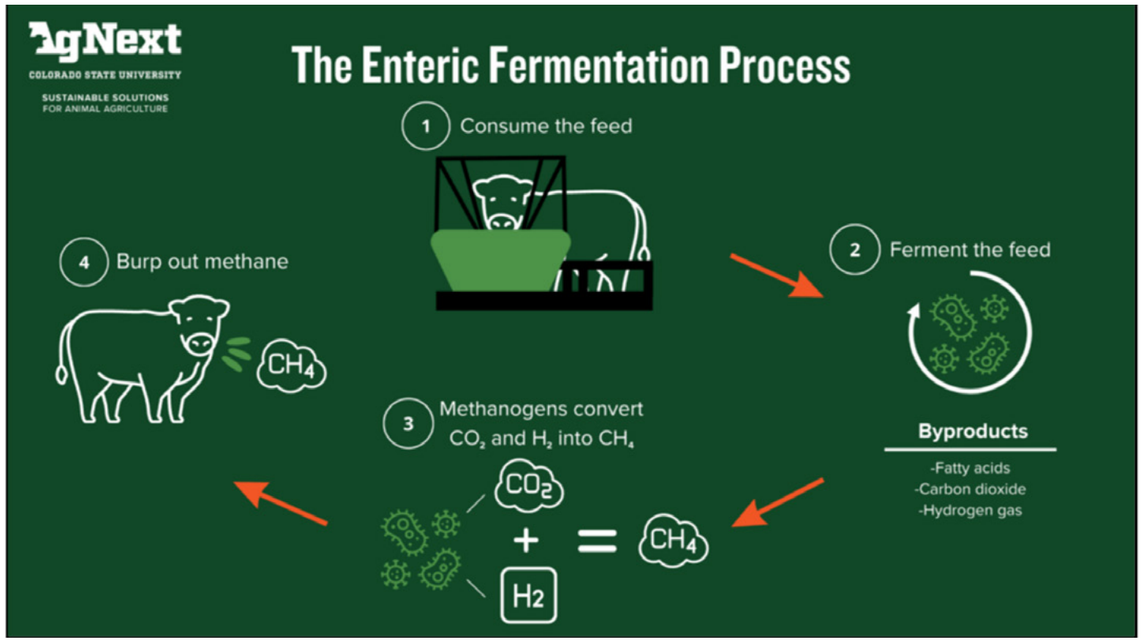

Figure 17: Photo Credit: AgNext, Colorado State University

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.

The Livestock Enteric Methane Emission Reduction Research Program (LEMER-RP) awarded $9.46 million to seven 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 2: Reduce Greenhouse Gas Emissions

CDFA convened the Manure Recycling and Innovative Products Task Force (MRIP) in 2021 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 and wet, which can make transporting it more costly than commercial fertilizer.

Stakeholder Feedback

Stakeholders asked that the state continue to implement the recommendations identified through the MRIP report, asking that the state recognize the potential benefits of integrating surplus dairy manure into the circular bioeconomy through the development of manure products and markets. They recommended that CDFA advance remaining actions through research and demonstration projects.

The MRIP task force released a final report providing recommendations on better utilizing dairy manure nutrients and supporting a circular bioeconomy, including methods that can also often reduce greenhouse gas emissions. Additionally, to support MRIP and provide technical background for policy recommendations, researchers at UC Davis have conducted research to provide an overview of the amount and location of surplus nutrients within California's dairy sector and evaluate selected manure treatment technologies capable of recovering manure nutrients in useful form or otherwise reducing surpluses safely. The following is a summary of their recommendations, which helped inform CDFA's CLIM³ATE-RP as well as the other CDFA incentive programs (described above):

- Prioritization and increased adoption of currently available 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 2: Reduce Greenhouse Gas Emissions

The California Dairy Emissions Model (CADEM) is a process-based tool designed to estimate emissions of greenhouse gases, such as methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O), as well as ammonia (NH_3) 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.[106] It can also support the evaluation of different emission mitigation strategies and help identify approaches that are both practical for producers and aligned with the methane emission reduction goal set under Senate Bill 1383.

Stakeholder Feedback

Stakeholders asked that the state's dairy methane reduction programs begin collecting data on other facets of dairy operations, including ammonia emissions and dust, nutrient leaching, groundwater protection, and worker health in dairy transition strategies

12.2.5 Convene researchers from around the world to track and advance enteric methane science and reduction strategies.

Goal 2: Reduce Greenhouse Gas Emissions

Since 2024, CDFA has worked with the UC Davis CLEAR Center to organize the State of the Science Summit on Reducing Methane from Animal Agriculture. This annual summit hosts researchers and implementers from around the world to hear informational presentations and panel discussions with leading experts in methane mitigation and animal science, connecting the dots between the scientific and regulatory aspects of feed strategies to reduce enteric emissions. The goal is to identify opportunities for collaboration and research that can help the dairy and beef industries meet our collective climate goals, such as the Global Methane Pledge. The Global Methane Pledge (GMP) was launched at COP26 by the European Union and the United States, and which has now been joined by many countries. To date, 159 countries and the European Commission have signed on to the GMP.

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 solids 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: Reduce Greenhouse Gas Emissions

Dairy farmers are finding innovative ways to address methane and reduce their environmental impact. Dairy digesters are specialized systems that capture the methane produced from anaerobic decomposition 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), 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 2022, the CPUC established biomethane procurement targets pursuant to SB 1440.[107] This initiative supports the procurement of 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. This program supports offtake of organic materials to further various state objectives for the production of biomethane in a range of applications. Municipal organic waste diverted to anaerobic digesters (SB 1383 organic waste diversion goals), agricultural and forestry management waste processed in gasifiers (avoiding agricultural burn and forest fire management), and dairy manure biogas captured in covered lagoons or anaerobic digesters (SB 1383 reduction of Short-lived Climate Pollutant (SLCP) emissions) can all be used to reduce methane emissions and effect productive use of upgraded biogas as biomethane injected into the California pipeline system. Biomethane injection offsets fossil natural gas consumption and reduces local pollution affecting California communities.

12.3.2 Promote utilization of manure solids as inputs for soil amendment products.

Goal 1: Improve the Bottom Line for Farmers

Another benefit of digester and non-digester manure management practices is that they allow further treatment of manure solids. Separated manure can be traditionally composted and sold as a soil amendment product for nearby farms and orchards. Alternatively, advanced manure management systems may result in other value-added products. One example is vermifiltration, also known as vermicomposting, a process where a dairy's manure wastewater is filtered through a bed of earthworms and wood chips which eventually produces a nutrient-rich vermicompost. This valuable soil amendment can be sold, providing another revenue source for farmers. By leveraging 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 developing an economic and more resilient agricultural system.

Dairy Manure and Irrigation Innovation

CDFA's State Water Efficiency and Enhancement Program (SWEEP) has now added sub-surface drip irrigation, including manure effluent mixing and application systems, as an eligible practice under 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.

Case Study: Enhancing Dairy Sustainability Through Improved Manure Management Technologies

Project Funding Program: Alternative Manure Management Program

Awarded Organization: Manuel and Maria Cardoso & Sons Dairy

Award Year: 2022

Project Implementation County: Merced

The new manure separator on the dairy.

CDFA's **Alternative Manure Management Program** (AMMP) provides financial assistance for the implementation of greenhouse gas emissions reducing, non- digester manure management practices on dairy and livestock operations. Tiberio Cardoso, whose family has been farming since 1981, is the Operations and Finance Manager for Manuel and Maria Cardoso & Sons Dairy. With AMMP funds, he and his family added additional manure separation technologies to improve their dairy's manure management system.

Solid-liquid separation equipment such as the sloped screen mechanical separator installed on the dairy can keep manure in a drier form and out of non-oxygenated conditions, emitting significantly less methane than liquid slurry or manure stored in ponds and allowing the components to be more efficiently reused. The solids could then be used for bedding, keeping housed cows cleaner and drier, and reducing sediment buildup in the flush lanes. The solid separation resulted in cleaner lagoon waters that lead to less solids accumulation around irrigation valves, helping prevent crop damage in those areas. Separation also increased lagoon storage capacity, which is a crucial benefit in years that they receive excessive rainfall. One surprising benefit Cardoso noticed is that manure separated in this fashion proved easier to store and keep dry in the winter months, which may help to further reduce methane emissions.

Cardoso notes that the AMMP funds made it possible to implement the climate smart practices they have wanted to incorporate but were not financially viable options for them. Beyond the greenhouse gas emissions reductions, they found financial savings too: "Separating the manure before it enters the ponds has saved us money that would have gone to pond cleanings; handling and moving drier manure has also reduced our hauling and spreading costs. Those cost savings will help keep us sustainable [in the] short- and long-term."

*"We think that society likes to paint dairymen as greedy money hungry operators, but in reality, our **number one priority is our animals** and their comfort along with protecting **our environment**. Our project provides **significant benefits** to our operation [by] **improving animal comfort** with improved bedding and also helping us meet environmental regulations, which is a **win-win situation.** This allows us to **remain sustainable in producing a food item that is a necessity in society.**" – Tiberio Cardoso*

Implementation

Strategy/Action	Goal Alignment	Lead Agency	Existing Initiatives
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: Reduce Greenhouse Gas Emissions	CDFA	Alternative Manure Management Program (AMMP), Dairy Digester Research & Development Program, Dairy Plus Program
12.1.2 Increase adoption of anaerobic digesters.	2: Reduce Greenhouse Gas Emissions	CDFA	Alternative Manure Management Program (AMMP), Dairy Digester Research & Development Program
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.	2: Reduce Greenhouse Gas Emissions	CDFA, CARB	
12.2.2 Support research dedicated to enteric emissions reduction strategies.	2: Reduce Greenhouse Gas Emissions	CDFA	CDFA Research, California Livestock Methane Measurement, Mitigation and Thriving Environments Research Program (CLIM^{3}ATE-RP), Livestock Enteric Methane Emission Reduction Research Program (LEMER-RP)
12.2.3 Promote research and development for novel methane reduction strategies.	2: Reduce Greenhouse Gas Emissions	CDFA	Manure Recycling and Innovative Products Task Force (MRIP) and final report
12.2.4 Support research to better quantify emissions from dairies.	2: Reduce Greenhouse Gas Emissions	CDFA, CARB	
12.2.5 Convene researchers from around the world to track and advance enteric methane science and reduction strategies.	2: Reduce Greenhouse Gas Emissions	UC, CDFA	
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: Reduce Greenhouse Gas Emissions	CDFA, CPUC	DDRDP, Low Carbon Fuel Standard (LCFS), Renewable Fuel Standard (RFS), Renewable Gas Standard (RGS), CPUC biomethane procurement targets
12.3.2 Promote utilization of manure solids as inputs for soil amendment products.	2: Reduce Greenhouse Gas Emissions	CDFA	

Summary and Conclusion

This Climate Resilience Strategy for California Agriculture (RSA) represents a comprehensive, forward-looking roadmap for strengthening the resilience of the state's agricultural sector in the face of climate change and related pressures. It brings together the deep and diverse expertise of California's farmers and ranchers, technical partners, community organizations, and public agencies to define not just the challenges before us, but the opportunities to act collaboratively and effectively for a stronger, more resilient future.

Ag Vision 2030 identified as its top strategic priority the need to "foster climate-smart, resilient, and regenerative food systems" and frames climate resilience as essential to the future prosperity of California's farms, food systems, and rural and urban communities alike. The RSA is intended to provide a forward-looking roadmap to achieve the priority set out in Ag Vision 2030, the State Board of Food and Agriculture's guiding vision for this decade. The RSA advances this priority by organizing concrete strategies and actions that protect ecosystems, strengthen economic viability, improve workforce wellbeing, and accelerate innovation in farming and ranching systems.

Across twelve key objectives, organized under three strategic pillars—supporting a thriving and resilient food sector, protecting natural systems critical to agriculture, and encouraging resilient agricultural practices—the RSA catalogs the actions California is already taking and identifies where additional effort and alignment are needed. The Strategy deliberately integrates a range of context, strategies and actions, case studies, stakeholder suggestions, and implementation tables for each key objective, reflecting a thoughtful blend of state action, lived experience, scientific insight, and policy analysis.

The RSA also aligns the actions for each objective with the overarching goals of improving the bottom line for farmers, reducing greenhouse gas emissions, supporting economic development, and providing health and environmental benefits. These goals create a coherent framework for moving from analysis and recommendations to implementation and impact across the agricultural landscape.

What we hope stakeholders take away from this Strategy is a sense of shared purpose and direction. This document is not merely a catalog of challenges—it is an expression of California's commitment to sustain, protect, and evolve its agricultural systems in the face of uncertainty. It is an invitation to producers, farmworkers, industry partners, researchers, state and local governments, and community members to take part in shaping the actions that will make our food systems more resilient, equitable, and innovative. The RSA is a tool for coordination—helping diverse actors understand common priorities, recognize areas of alignment, and invest collective energy in solutions with measurable impact.

Importantly, this Strategy is neither static nor finished. The climate challenges we face continue to evolve, as do the scientific understanding, technologies, and economic contexts that shape agricultural resilience. As such, the RSA is designed to be a living framework—one that will be refined and updated to incorporate new insights, feedback from implementation experiences, and emerging opportunities for adaptation and mitigation. Through ongoing engagement and iterative improvement, this Strategy will continue to guide California agriculture toward a more resilient and prosperous future.

In closing, the Climate Resilience Strategy for California Agriculture stands as both a milestone and a starting point. It embodies a collective commitment to anticipate and respond to the realities of a changing climate, protect the natural systems that sustain agriculture, and ensure that the state's farms, communities, and ecosystems thrive for generations to come.

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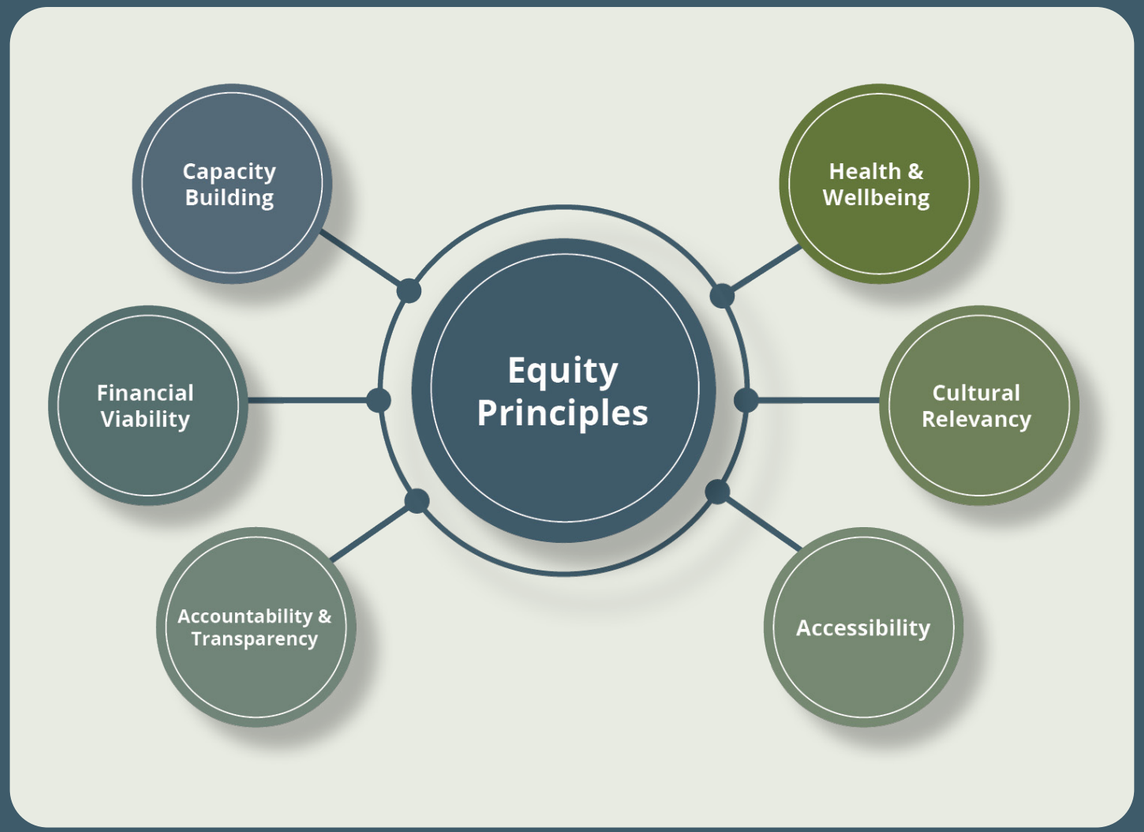
Appendix A

Equity Principles



CALIFORNIA DEPARTMENT OF
FOOD AND AGRICULTURE

Integrating Equity Principles for Agriculture

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

Integrating Equity Objectives

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?

Integrating Equity Objectives

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?

Integrating Equity Objectives

- 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?