

California Climate and Agriculture Network

# Ready... Or Not?

An Assessment of California Agriculture's  
Readiness for Climate Change

March 2011



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# Executive Summary

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Dependent on weather and the availability of natural resources, California agriculture is uniquely vulnerable to the effects of climate change. California agriculture's contributions to greenhouse gas emissions are relatively small compared to those of other sectors of the economy, accounting for only 6 percent of the state's total emissions. However, agriculture has the potential to offer unique and significant climate solutions, including carbon sequestration and on-farm renewable energy generation.

Given California's leadership in tackling climate change, and its importance globally as an agricultural producer, it is essential to understand to what extent state government is supporting California agriculture in addressing its unique climate change challenges. To understand this, the California Climate and Agriculture Network conducted an assessment of the adequacy and availability of resources for California agriculture to address climate change.

## Focus on Sustainable Agricultural Solutions

Farming systems that reduce the reliance on synthetic inputs, conserve natural resources and provide multiple environmental benefits offer promising opportunities within agriculture to mitigate and adapt to climate change. Sustainable and organic systems offer some of the best opportunities in agriculture to reduce GHG emissions, sequester carbon and increase agriculture's resilience to climate change impacts.

Sustainable and organic farming systems apply an integrated, biological approach to farm management that emphasizes natural resource conservation, reduced farm inputs, biological and cultural control of pests, soil-building practices and grass-based livestock production systems. Because these systems function differently than their conventional counterparts, research must be designed to examine their unique benefits for reducing GHG emissions and adapting to climate change.

## Study Goals and Methodology

In an effort to qualify and quantify the resources available in California for agriculture to mitigate and adapt to climate change, we identified the following goals for this study:

1. To identify state and federally funded research projects that address climate change mitigation and adaptation strategies specific to California agriculture.
2. To assess the extent to which sustainable and organic agricultural perspectives are incorporated in publicly funded California climate change and agriculture research.
3. To assess the state of technical assistance resources available to California farmers and ranchers.
4. To assess the availability of conservation incentives for California farmers and ranchers.

We divided the analysis of the status of resources available for California agriculture to address climate change into three categories: research, technical assistance and financial incentives.

We used the following criteria to identify publicly funded research included in our review:

1. California-based research
2. Directly addressed mitigation and/or adaptation agricultural practices to climate change
3. Funded or conducted since 2007

In an attempt to characterize some core aspects of sustainability in agriculture, we used the following six indicators of sustainability to evaluate each climate change and agriculture mitigation or adaptation study for its inclusion of sustainable agriculture practices and approaches: organic systems; integrated biological systems; water and energy efficiency and conservation; reduced inputs; economic impacts; social impacts.

To understand the state of technical assistance for the state's farmers and ranchers, we spoke to current and retired state and federal staff, reviewed newspaper articles and attended government agency meetings.

To analyze the status of direct incentive programs in the state to support on-farm conservation efforts, we reviewed both state and federally funded programs available to California producers.

## **Findings**

### **A. Research Projects**

In our review of state and federally funded research, we identified 115 California agriculture and climate change research projects initiated since 2007. Of these, we found only 39 research projects that focused on California agriculture-specific climate change mitigation and adaptation activities. These studies are concerned with the practice of farming; they seek to understand how changes in production practices can provide climate benefits.

Of the 39 studies we found:

- 10 percent included organic systems as a central component of the research.
- Nearly 50 percent of the studies examined the impacts of integrated biological farming systems.
- 33 percent of the studies explored water and energy efficiency and/or natural resource conservation.
- Reduced inputs were included in approximately 30 percent of the studies.
- Economic impacts were examined in approximately 40 percent of the studies.
- Social impacts were examined in only 15 percent of the studies.

### **B. Technical Assistance**

We found that budget cuts have eliminated offices and reduced staffing levels for all branches of publicly funded technical service providers for agriculture. In summary:

- The number of on-farm Cooperative Extension advisors peaked in 1969 at 380 advisors, and the number of Cooperative Extension specialists peaked at 208 specialists in 1988. Today, there are only 200 Extension on-farm advisors and 119 specialists, down 40 percent since the early 1990s.
- In comparison, Texas, second in the country to California in agricultural product sales, has 900 county-based Extension specialists.
- State budget cuts have reduced staffing levels and programming for the Resource Conservation Districts.
- Staffing levels at the Natural Resource Conservation Service (NRCS) of the USDA are down 7 percent from 2005 to present, despite increased demands for farm bill conservation programs.

### **C. Direct Conservation Incentives**

In our review of incentive programs for agricultural producers, we were concerned with access to direct incentives for agricultural producers. Highlights from our review include:

- Unlike other agricultural states, California lacks direct incentive programs for producers to adopt on-farm conservation programs.
- The USDA is the largest source of funding for agriculture conservation activities in the country. In 2009, 70 percent of the California farmers and ranchers who applied for USDA farm bill conservation programs were denied access to the programs because of a lack of funding.

## Conclusion

California has made considerable progress towards understanding how climate change may impact the state's agriculture sector. But too few research studies have been conducted on how agriculture might respond effectively to reduce GHG emissions, sequester carbon and adapt to a changing climate. And fewer studies still take a sustainable and organic agricultural perspective. Moreover, the state's ability to provide technical assistance and conservation incentives for farmers and ranchers is woefully inadequate to meet the complex challenges of climate change after decades of budget cuts have reduced staffing levels and eliminated programs.

## Recommendations

### #1: Invest in California Agriculture

- Invest a portion of cap-and-trade auction revenue in research and demonstration, technical assistance and financial incentives for farmers and ranchers to adopt practices, technologies and farming systems that reduce GHG emissions, sequester carbon and adapt to climate change while providing environmental co-benefits such as improved air quality, water conservation and increased wildlife habitat.
- To oversee the implementation of this grants program, form an advisory committee made up of California researchers, agricultural producers, processors, nonprofit representatives and state and federal agency representatives with expertise in climate change and agriculture issues.

### #2: Prioritize Whole Systems and Participatory Research

- Research that takes into account whole farm systems should be emphasized and sustainable and organic farming systems approaches should be included in future research projects.
- Researchers who work directly with producers to conduct their research should be especially encouraged.

### #3: Build Bridges Between Researchers and Growers

- The state should re-invest in UC Cooperative Extension and Resource Conservation Districts with the eventual goal of returning to early 1990s staffing levels.
- Given the complexities of climate change, new and on-going training opportunities for farm advisors and specialists will be needed.
- Re-investment in the UC Sustainable Agriculture Research and Education Program (SAREP) is also needed to provide a hub for long-term farming research trials ongoing sustainable agriculture research and demonstration grants and relevant educational programming for producers and technical service providers.
- As state budget cuts threaten the ongoing viability of UC Cooperative Extension, these efforts should be funded by cap-and-trade revenue.

### #4: Support Stewardship

- CDFA's Office of Agricultural and Environmental Stewardship (OAES), eliminated in 2009, should be reestablished and include new staff with climate change expertise. This office would build support for agricultural conservation practices among urban constituents and enhance understanding and cooperation with environmental and food advocates.

### #5: Develop Conservation Incentives

- California can learn from other states like Wisconsin, Minnesota, Iowa and Pennsylvania that have developed direct producer incentives to support conservation goals.
- A reestablished OAES at CDFA should work with agency partners to develop a climate-oriented agricultural conservation incentive program, funded by cap-and-trade revenue.

#### **#6: Comprehensively Address Agricultural Adaptation to Climate Change**

- Create an Office of Climate Change Adaptation with an Agriculture Division.
- The office should be housed in either the Natural Resources Agency or the Governor's Office, using cap-and-trade revenue, state bond or federal funding to establish it.
- The office should include an Agriculture Division that prioritizes coordination with the California Air Resources Board and California Department of Food and Agriculture to provide research, technical assistance and cost sharing for farmers and ranchers to adopt practices that reduce agriculture's vulnerabilities to a changing climate.
- Given California's vulnerability to water scarcity, which will only increase as climate change impacts are realized, particular attention should be paid to expanding the use and diversity of water-conserving agricultural practices.

# Introduction

California agriculture is the most diverse and productive agricultural system in the United States. The state's farms and ranches supply nearly 50 percent of the country's fruits, nuts and vegetables, and California is the nation's top producer of dairy products. A \$36 billion industry, California agriculture covers over a quarter of the state's land mass and accounts for 80 percent of the state's developed water use. Thus, the future of California agriculture is not only of state significance, but has national implications as well.

For these reasons, climate change scenarios for California's agricultural system are of state and national concern. And as a sector of our economy that is dependent on weather and the availability of natural resources—especially water—agriculture is also uniquely vulnerable to climate change impacts.

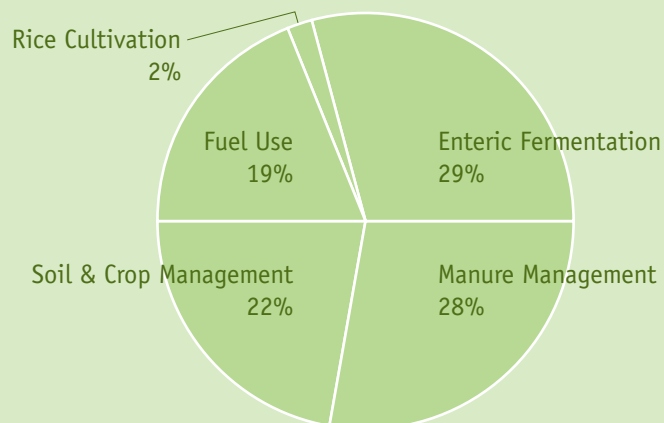
Climate change models suggest that by 2050 California will experience extreme water shortages. Increases in temperature threaten to reduce crop yields, and more extreme weather events, such as increased heat waves, flooding and droughts, could significantly hamper agricultural production. Agriculture has much to lose if climate change is not addressed and the worst impacts averted.

California agriculture's contributions to greenhouse gas emissions are relatively small compared to other sectors of the economy: It accounts for only 6 percent of the state's total emissions. However, agriculture has the potential to offer unique and significant climate solutions. See Figure 1 for a breakdown of agriculture's contributions to the state's GHG emissions.

## GHG Emission Sources in California Agriculture

Agriculture contributes approximately 6 percent of the state's total GHG emissions. More than half of agriculture's emissions come from livestock in the form of enteric fermentation (the gases released by livestock) and manure management. The second-largest contributor is crop and soil management (including synthetic fertilizer use and manure), accounting for nearly a quarter of agriculture's GHG emissions. Here we show the breakdown of sources of GHG emissions from California agriculture, as estimated by the California Air Resources Board.

**Figure 1: California agricultural GHG emissions inventory**



Source: California Air Resources Board. [http://www.arb.ca.gov/app/ghg/2000\\_2006/ghg\\_sector\\_data.php](http://www.arb.ca.gov/app/ghg/2000_2006/ghg_sector_data.php)



Agriculture and forestry are the only sectors in our economy that can sequester atmospheric carbon in soils and woody biomass. Moreover, agriculture can also produce on-farm renewable energy, thereby reducing GHG emissions related to energy consumption, and take actions to reduce emissions from two potent greenhouse gases—nitrous oxide and methane. We describe agriculture’s potential contributions to climate change mitigation in greater detail in Section Two.

As described in Section Two below, California agriculture will be challenged to reduce its significant vulnerabilities to the effects of climate change. A diversity of adaptation measures will be needed to enhance its resilience, among which are water conservation and efficiency measures, farmland preservation, and increased biological and crop diversity.

## **California Leadership in Climate Change Policy**

California is leading the country in its efforts to reduce GHG emissions and shift towards clean energy technologies. The Global Warming Solutions Act of 2006, known as Assembly Bill 32 (AB 32), is the most comprehensive and ambitious climate law in the country. It requires California to reduce its GHG emissions to 1990 levels by 2020.

The state has also begun to address issues of climate change adaptation. In 2009, the Natural Resources Agency released its climate change adaptation strategy plan for the state, which outlines steps to help industries and ecosystems cope with the inevitable changes in climate the state will experience in the near and long term.

Given California’s leadership in tackling climate change, and its importance globally as an agricultural producer, it is important understand to what extent these state government efforts support California agriculture in addressing its unique challenges to climate change.

To determine this, the California Climate and Agriculture Network conducted an assessment of the adequacy and availability of resources available for California agriculture to address climate change.

## **Resources to Support Climate-Friendly Agricultural Systems**

California farmers and ranchers will need information on how to cope with a changing climate. Climate change poses numerous questions and has significant implications for the business of farming and ranching. Producers will need to have answers for these questions, among them:

- What on-farm practices may help conserve water while maintaining yields?
- How can management practices address new weed and pest pressures?
- What soil management practices can increase carbon sequestration and reduce nitrous oxide emissions?
- How will regional variability in climate change impact production choices?
- How can on-farm renewable energy generation complement a farm’s production needs?
- How can California agriculture remain viable in the face of increasing climate-related pressures?

To answer these and related questions, we need research, based on the California experience, that deepens our understanding of how agriculture might respond to shifts in climate. Since 2000, state agencies have invested \$75 million in climate change science.<sup>1</sup> It is important to understand how this significant investment has furthered our understanding of the climate change mitigation and adaptation opportunities for California agriculture.

In addition to studying climate change and agriculture issues, it is essential to translate research findings into on-the-ground change. Farmers and ranchers must have access to technical experts who are well-trained, know the science and can work with producers to address their needs.

Finally, just as the state of California has prioritized renewable energy production by incentivizing its development in the state, we must do the same to support conservation-oriented agricultural practices and farming systems that provide climate benefits. In so doing, the state can help reduce the financial risks associated with adopting climate-friendly agricultural practices, and it can promote resource-conserving farming systems that have multiple environmental and health benefits.

## Focus on Sustainable Agricultural Solutions

As we discuss in greater detail in Section Two, sustainable and organic agricultural farming systems offer some of the best opportunities in agriculture to reduce GHG emissions, sequester carbon and support climate change adaptation. For example, in organic systems, the use of synthetic fertilizers and pesticides is prohibited; instead, they utilize less fossil fuel intensive practices for soil and pest management. Consequently, organic farming systems are up to 30 to 50 percent less energy-intensive than their conventional counterparts, resulting in a lower carbon footprint.<sup>2</sup>

Sustainable and organic farming systems apply an integrated, biological approach to farm management that emphasizes biological and cultural control of pests; soil-building practices such as cover crops, manure and/or compost to improve soil fertility; and grass-based livestock production systems. Successful integrated, biological farming systems enable farmers to maintain yields and quality while greatly reducing their reliance on off-farm chemical inputs, including pesticides and synthetic fertilizers. Because sustainable and organic farming systems function differently than their conventional counterparts, research to examine their benefits and compare them to conventional practices must be designed to take into account integrated, whole farms systems and their ability to reduce GHG emissions and adapt to climate change.

If we ignore sustainable and organic agricultural systems, we will miss important opportunities to achieve GHG emission reductions, obtain other environmental and health benefits and support a more resilient agriculture.

## Scope of Study

The California Climate and Agriculture Network reviewed the state of publicly funded resources aimed at assisting California agriculture in addressing climate change. The goals of our review were the following:

1. **Identify state or federally funded research projects that address climate change mitigation and adaptation strategies specific to California agriculture.** Much of the research to date on climate change strategies for agriculture has been conducted in the Midwest, where soils, cropping and weather patterns differ significantly from California's. What is the status of California-based agricultural research that deepens our understanding of climate change mitigation and adaptation potential in California agriculture?
2. **Assess to what extent sustainable and organic agricultural perspectives are incorporated in publicly funded California climate change and agriculture research.** Specifically, we wanted to know whether researchers are considering sustainable and organic farming systems when examining methods to reduce GHG emissions, sequester carbon or adapt to climate change.
3. **Assess the state of technical assistance resources available to farmers and ranchers.** We know that budget cuts over the years have curtailed education and outreach resources for California producers. We wanted to know to what extent these cuts have limited the state's ability to provide science-based technical support for farmers and ranchers coping with new climate pressures.
4. **Assess the availability of conservation incentives for California farmers and ranchers.** Finally, we examined the extent to which conservation-oriented agricultural practices, many of which may provide climate benefits, are being promoted in California. Other states offer direct incentives for agricultural producers to voluntarily use agricultural practices that support on-farm conservation practices. What about California?

## **Report Overview**

The first two sections of the report offer background on climate change and agriculture issues in California. Section One reviews climate change impacts on California agriculture. Section Two provides a summary of the research on the climate change solutions offered by resource conserving practices in agriculture. Section Three summarizes the study methodology. The study findings are detailed in Section Four. Finally, in Section Five, we offer recommendations for how California, in the face of climate change, may move forward with providing the necessary resources to support a viable California agriculture in the decades to come.

# 1.

## Climate Change Impacts on California Agriculture

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Climate change presents a significant challenge for agriculture. Dependent on weather and the availability of natural resources, especially water, agriculture is uniquely vulnerable to the effects of climate change.<sup>3</sup> Here, we summarize how climate science predicts the future impacts of rising temperatures and shifts in weather patterns on California farming and ranching.



## 1.1. Changing Water Patterns and Supply

Constrained water resources will be among the most challenging effects of climate change for California agriculture. Three-quarters of the state's water supply originates in Northern California, primarily from water stored in Sierra Nevada snowpack.<sup>4</sup> In the coming years and decades, as temperatures warm, climate scenarios suggest that precipitation will increasingly fall in the form of rain rather than snow during the winter months.<sup>5</sup> Some research has suggested that snowmelt runoff could occur up to two months earlier than current averages.<sup>6</sup>

Earlier snowmelts combined with heavy rain events in the winter and spring will likely put pressure on reservoir operators to release stored water earlier in the season to avoid flooding, reducing available water supply during the crucial growing months of late summer and early fall.<sup>7</sup>

Changes in growing seasons will also impact agricultural water use. In the near term, warmer temperatures will allow for longer growing seasons, which will consequently increase water requirements for crops<sup>8</sup> at a time when water supply reliability is decreased.<sup>9</sup>

Limited water supplies will likely lead to heightened competition between urban, agricultural and environmental uses.<sup>10</sup> Even assuming adoption of increased water conservation and efficiency measures, urban water use is expected to rise more than 10 percent between 2020 and 2050.<sup>11</sup> Moreover, California's State Water Resources Control Board has developed an assessment of water flows required to meet the needs of aquatic species in the Sacramento-San Joaquin Delta ecosystem, and found that diversions may need to be reduced by as much as 50 percent,<sup>12</sup> an amount that could increase as water becomes less available.

A study of California water demand under two climate change scenarios suggests that agricultural water supplies may be 20 to 23 percent below demand targets by 2050.<sup>13</sup> This could have significant economic repercussions for California agriculture. For example, one study projected that while current constraints in water supply cost California agriculture an average of \$200 million annually, under climate change scenarios with greatly reduced water availability, annual costs to California agriculture by 2050 could be as high as \$800 million or more.<sup>14</sup>

Decreased water supplies may also hurt farmland values. One study found that with reductions of one to two acre-feet of available water, farmland values could decrease up to \$1,700 per acre.<sup>15</sup>

## 1.2. Reduced Winter Chill Hours

Warming temperatures are threatening one of the state's most lucrative sectors of the agricultural economy—the nut and fruit tree industry. Proper setting of fruit requires between 200 and 1,200 winter chill hours per season, during which time temperatures drop below 7 degrees Celsius (45 degrees Fahrenheit).<sup>16</sup> Chill hours in California have been decreasing since the 1950s and predictions are that by the end of the century 50<sup>17</sup> to 90 percent<sup>18</sup> of current chill hours will be lost in parts of the Central Valley, the state's primary fruit and nut tree growing region.

Crops such as apples, cherries, almonds and pears that require long chill hours may have extremely limited growing ranges by 2050, and by the middle to end of the 21<sup>st</sup> century some of the main tree crops currently grown in California will likely no longer be productive.<sup>19,20</sup> Other perennial crops in the state that will likely be impacted are avocados, grapes<sup>21</sup> and other nut<sup>22</sup> and stone fruit tree crops.<sup>23</sup> Though warmer nights have positively impacted oranges<sup>24</sup> and wine grapes in some cases,<sup>25</sup> continued warming will create conditions unfavorable for production of many wine grape varieties in the future.<sup>26</sup>

Continued production of many of these fruits will require that farmers adopt new cultivars better suited to the changed conditions, shift crops altogether or move production further north or “upslope” to higher elevations.<sup>27</sup> However, these scenarios present their own challenges, including transition costs and possibly increased production costs.

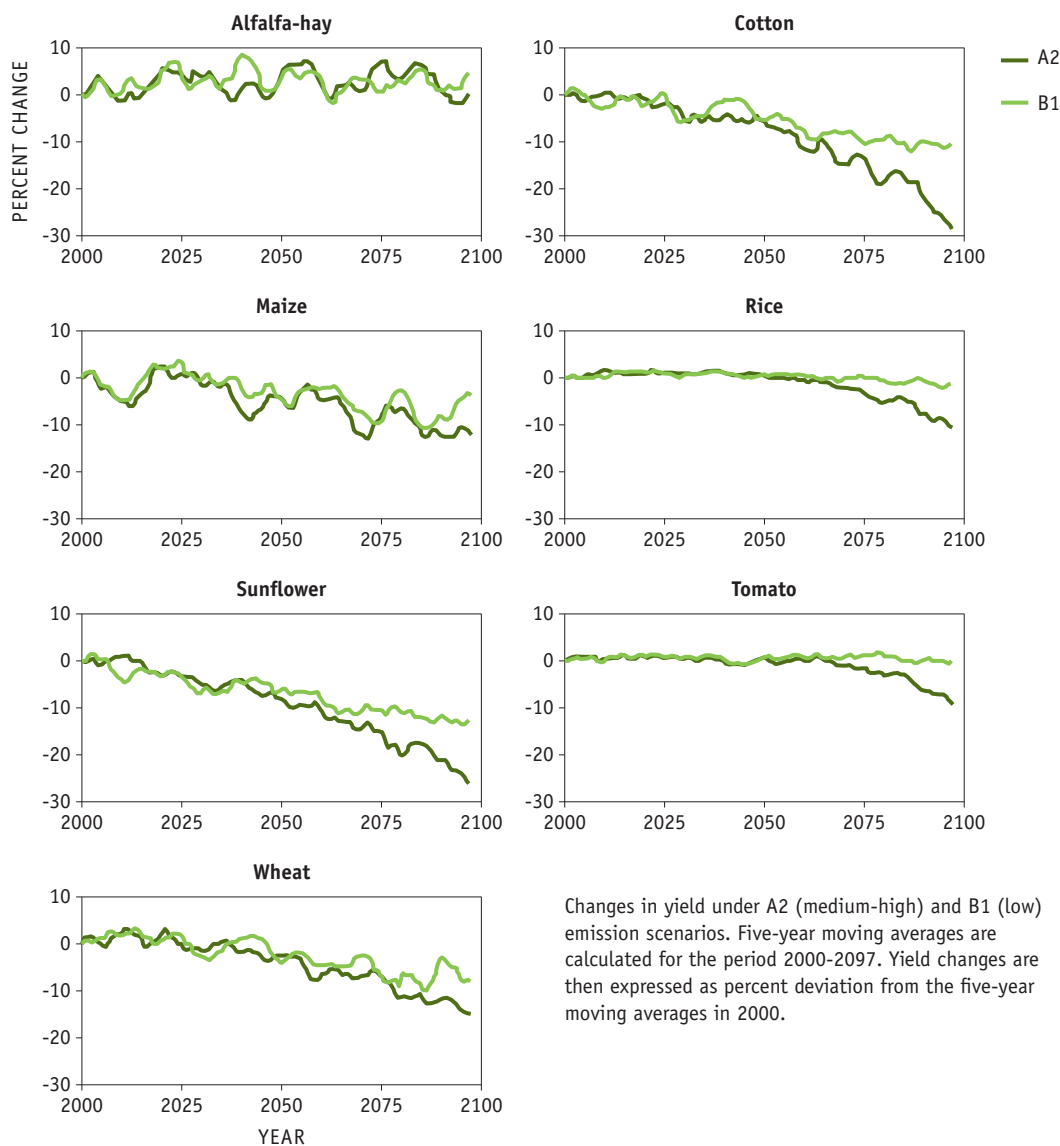
## 1.3. Decreased Crop Yields

Warmer temperatures will likely extend the growing season and increase crop yields in the near term, but such benefits will be limited. Longer growing seasons will put additional pressure on resource use, and new evidence suggests that many crops may face yield losses in the long term.

The U.S. Climate Change Science Program noted that annual crops—including rice, corn and sorghum—will likely have notable decreases in crop yields in the coming decades.<sup>28</sup> Temperature increases may also negatively affect tomato yields.<sup>29</sup> Current U.S. growing regions for corn, soybeans and cotton may have yield decreases of 30 to 46 percent by the end of the century under the slowest predicted warming scenario and by 63 to 82 percent under the most rapid warming scenario.<sup>30</sup>

As described in Figure 2, California climate models suggest that even the slowest warming scenarios (scenario B1) will have an effect on crop yields for a variety of annual plants. Cotton, corn, sunflower and wheat yields may decrease an average of three to eight percent by 2050. Cotton and sunflower will face even greater yield losses as soon as 2025 and by the end of the century may decrease as much as 29 percent.<sup>31</sup>

**Figure 2. Two warming scenarios modeling crop yields, shown in 25-year increments from 2000 to 2100<sup>32</sup>**



## 1.4. Rising Weed, Pest and Disease Pressures

Although increases in carbon dioxide (CO<sub>2</sub>), the primary driver of global warming, may increase plant growth, weed and pest populations are also predicted to increase.<sup>33</sup> Crops grown at elevated CO<sub>2</sub> levels may have up to twice as many insects and increased levels of insect growth and feeding compared to control groups.<sup>34</sup> Warmer temperatures will likely lead to the northern migration of invasive pests and in some cases may eliminate the cold temperatures that historically have kept the populations of some species in check.<sup>35</sup>

As weed growth intensifies, herbicide use may also increase. Research predicts that glyphosate, the most widely used herbicide in the United States, will continue to lose efficacy as its overuse results in herbicide resistance in more weed species. In response, some growers may increase the volume, types and potency of herbicide applications in the future, which may add to production expenses and exacerbate pesticide pollution problems.<sup>36</sup>

## 1.5. Vulnerabilities of Livestock Agriculture

Livestock production may be negatively affected by changes in climate as a result of increased pests and diseases. Elevated temperatures could increase the persistence and dispersal of animal pathogens.<sup>37</sup> Warmer temperatures can cause increases in mortality and/or decreases in productivity as a result of physiological stress and lower feed consumption. In the context of feedlots, higher temperatures will likely increase the production of methane, ammonia and other gases associated with ruminants. Moreover, increased heat waves and rising temperatures will likely lead to overall reductions in meat, egg and dairy production as well as the reproductive capability of livestock.<sup>38</sup>

## 1.6. Extreme Weather Events

Climate change has the potential to increase the number and intensity of extreme weather events in the state,<sup>39</sup> which may have profound short-term impacts on agriculture. Flooding in the Delta and Central Valley farmland is likely to increase from the combination of rapid snow melt resulting from warmer temperatures in the Sierra Nevada and increased winter and spring rainfall.<sup>40</sup>

The magnitude and persistence of droughts are also expected to increase, with some climate models suggesting increased moderate droughts in the state and other models suggesting less frequent but more severe droughts.<sup>41</sup>

Extreme temperatures may further exacerbate difficult agricultural conditions. Vulnerabilities to heat, particularly for flowering crops, may negatively affect growth. For example, research suggests that tomatoes suffer losses as a result of extreme temperature events including heat waves and late frosts. Heat waves may also place additional demands on water and irrigation, further restricting available supplies.<sup>42</sup>

## 1.7. Summary

Agriculture has much to lose if the worst impacts of climate change are not averted. Historically, insurance claims related to crop losses from excess moisture, cold spells and heat waves cost tens of billions of dollars annually in the United States, and are likely to increase as extreme weather events become more common.<sup>43</sup>

As agriculture only accounts for 6 percent of the state's GHG emissions, most of the reductions in GHG emissions will have to come from other sectors. But agriculture can and must be part of the climate change solution by not only reducing its own GHG emissions, but also sequestering atmospheric carbon and reducing its vulnerabilities to the inevitable changes in our climate.



**Table 1. California agriculture by the numbers**

All California Agriculture <sup>a</sup>	California	Percent of U.S. Total
Number of farms and ranches	81,500	< 4%
Average farm size	312 acres	418 acres
Acres of farm/ranch land	25.4 million acres	2.75%
Value of cash farm receipts	\$36.2 billion	11.2%

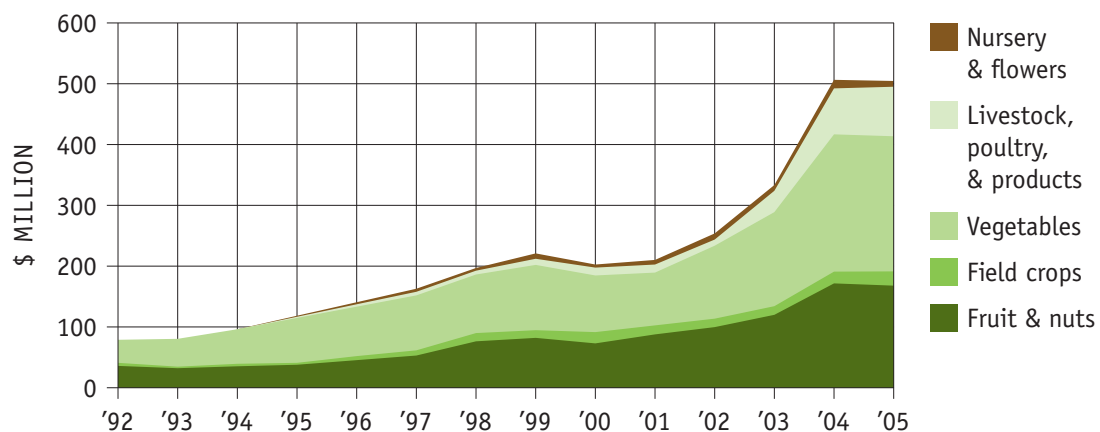
  

Organic Agriculture <sup>b</sup>	California	Percent of U.S. Total
Acres of organic farm/ranch land	470,903 acres	12%
Number of organic farms	2,714	19%
Organic product sales	\$1.15 billion	36%

<sup>a</sup> Source: USDA National Agricultural Statistics Service, 2008.

<sup>b</sup> Source: USDA National Agricultural Statistics Service Organic Production Survey, 2008.

**Figure 3. Growth in California organic sales 1992-2005**



Source: CDFA Organic Program. Compiled by Karen Klonsky, Agricultural & Resource Economics, UC Davis.



## 2.

# Agricultural Solutions to Climate Change

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To get a complete picture of the carbon footprint of a farming or ranching operation and the opportunities within it to reduce GHG emissions and sequester carbon, it is important to consider agricultural practices as integrated parts of the whole system. In biological systems such as agriculture, altering one practice to reduce GHG emissions may lead to the unintended consequence of increasing GHG emissions elsewhere in the system.

In this section, we summarize how conservation practices on farms and ranches may help to reduce GHG emissions, sequester atmospheric carbon and bolster agriculture's resilience in the face of a changing climate.



## 2.1. Energy Efficiency and On-Farm Renewable Energy Production

Reducing the amount of energy consumed on farms and ranches should be among the first practices producers consider in their attempts to lower the carbon footprint of agriculture. Energy efficiency measures have the added benefit of providing energy and cost savings to farms and ranches while reducing GHG emissions. Energy audits can reveal energy efficiency opportunities within an operation and may include such practices as properly inflating tractor tires to reduce fuel waste,<sup>45</sup> repairing water pumps to increase efficiency and/or reducing pumping time and maintaining farm vehicles and equipment.<sup>46</sup>

California farms and ranches also have the potential to produce renewable energy and become more energy-independent and self-reliant. Wind turbines,<sup>48</sup> solar panels,<sup>49</sup> anaerobic digesters and biomass projects on farms and ranches can increase the state's production of renewable energy and generate income for producers from the sale of excess energy or in some cases through lease agreements or royalties. Localizing energy generation has the additional benefit of circulating energy dollars that strengthen the economies of rural communities.

*“Carbon sequestration and GHG emission reductions are possible [in agriculture], but there is no single land management practice or change in inputs that could mitigate the carbon released from agricultural practices... Therefore, it is only the integration of different management strategies that shows considerable potential for carbon mitigation as well as provides important cobenefits to ensure the future sustainability of California agriculture.”*

Emma Suddick et al., 2010.

The potential for California agricultural crop soils to reduce greenhouse gas emissions.<sup>44</sup>

## 2.2. Practices to Reduce Greenhouse Gas Emissions and Sequester Carbon

Research is demonstrating the potential of agricultural practices to both reduce GHGs and sequester carbon. However, the relationships are complex and influenced by soil types, regional climates, cropping systems, and timing and combinations of practices. Further research is needed to understand these relationships and provide useful technical assistance to producers tailored to their circumstances.

### 2.2.1. Soil Management

Changes in soil management practices in agriculture can decrease GHG emissions and sequester atmospheric carbon. Agriculture and forestry offer the only currently available “sinks” of carbon CO<sub>2</sub>, the primary greenhouse gas. Agriculture and forestry can remove carbon dioxide from the atmosphere by storing it in soils and woody biomass, a process known as carbon sequestration.<sup>50</sup>

Among the soil management practices that have the greatest potential to sequester carbon are reductions in synthetic fertilizer use, use of cover crops, perennial cropping, and conservation tillage.<sup>51</sup> As noted in a recent California Energy Commission study, these types of soil management practices, when used in combination, offer the best opportunities to build soil organic matter and sequester carbon.<sup>52</sup>

Cover crops or green manures have been found to increase soil carbon, on average, 1.5 to 4 times as much as land under cultivation.<sup>53</sup> Composting and the addition of organic amendments have also resulted in increased carbon storage in soils.<sup>54</sup>

Studies reviewing the carbon sequestration potential of conservation tillage are mixed and sometimes contradictory. A five-year study in California's San Joaquin Valley found that conservation tillage alone did not increase soil carbon, but combined with cover cropping there was some accumulation at depths of up to 30 cm.<sup>55</sup> Another study in California's Central Valley found that the combination of conservation tillage and cover cropping enhances soil organic carbon and also has a positive impact on yield and the populations of soil microorganisms necessary for producing soil organic matter.<sup>56</sup> Thus, the potential for conservation tillage to increase carbon sequestration may be elevated with the use of additional soil management practices including cover crops, which can contribute to building soil organic matter.<sup>57,58</sup>

However, practices to increase carbon sequestration in soils may influence the nitrogen cycle of the soil and lead to short-term increases in nitrous oxide (N<sub>2</sub>O) emissions. For example, USDA researchers comparing the total carbon footprint of three different grain systems in Maryland found that the organic grain system in some years had higher N<sub>2</sub>O emissions compared to conventional no-till and chisel plow grain systems.<sup>59</sup> However, when comparing the total emissions of the three systems, looking at N<sub>2</sub>O emissions, carbon content of soils and fossil fuel consumption, the organic system had lower overall emissions than the two conventional systems, despite the higher N<sub>2</sub>O emissions in the organic system.

Therefore, it is important for producers and policymakers to understand the interactions between the carbon and nitrogen cycles of soils, as well as the ways the cycles influence the total GHG emissions.

In addition to minimizing GHGs and enhancing carbon sequestration, there are many co-benefits associated with alternative soil management practices, such as cover cropping, compost and manure use, including improved soil fertility; increased soil water infiltration; improved air and water quality; decreased erosion; enhanced wildlife and beneficial insect habitat and weed control.<sup>60</sup>

### 2.2.2. Perennial Landscapes

Incorporating trees, shrubs or other types of woody vegetation into rangeland or farm landscapes can help to sequester carbon in significant quantities.<sup>61,62</sup> Carbon dioxide is absorbed by trees and plants and stored in the woody biomass above ground and in the root system. One study in the Central Valley found that hedgerows and planted riparian corridors stored 18 percent of the farm-based carbon while occupying only 6 percent of the land mass.<sup>63</sup>

Riparian zones vegetated with woody plants can almost double carbon sequestration, compared to adjacent farmland, and provide other benefits, such as nutrient buffer strips to protect water quality and habitat biodiversity above and below ground.<sup>64</sup> In California, there may be several strategies to increase carbon sequestration in rangeland with the replanting of oak woodlands offering the greatest carbon sequestration potential.<sup>65</sup>

### 2.2.3. Sustainable Livestock Management

Livestock production accounts for more than half of California agriculture's GHG emissions. The sources of livestock emissions include gases emitted directly from animals (known as enteric fermentation), manure management and emissions associated with feed, energy and water use during livestock production.

Sustainable management of rangelands—which cover half of the total land area of California<sup>66</sup>—can be an effective tool for carbon sequestration and GHG emission reductions generally. Cattle grazing can increase above-ground productivity of vegetation and species richness,<sup>67</sup> which is frequently correlated with increased carbon in the soil.<sup>68</sup> Grazing has also been found to increase the rate of soil carbon sequestration.<sup>69,70</sup> In a study modeling the impacts of various dairy and beef management practices it was estimated that intensive grazing and rotation through paddocks increased carbon sequestration by 10 percent, and this was increased to 15 to 30 percent when combined with improved production efficiency and no-till feed production.<sup>71</sup>

Livestock grazing on high-quality forage or a diet containing plants typically found in pastures may emit less methane.<sup>72,73,74</sup> While research comparing methane emissions from pasture versus feedlot finishing are still limited, evidence suggests that finishing cattle on pasture rather than on grain may reduce methane emissions.<sup>75</sup> Studies comparing the energy inputs required for different livestock management systems also suggest that conventional feedlot livestock require twice as much fossil fuel energy inputs compared to grass-fed livestock, due in large part to the use of synthetic fertilizers and pesticides used to produce the feed crops.<sup>76</sup>

Altering livestock waste management practices can also reduce GHG emissions. Manure lagoons or slurries often produce methane and nitrous oxide,<sup>77</sup> two potent GHGs, as the result of the anaerobic (no or low oxygen) decomposition of manure. When manure is applied to the land instead of stockpiled or stored in large ponds or lagoons, methane emissions can be reduced.<sup>78</sup> Because animal manures contain about 40 to 60 percent carbon, its application to land can increase the soil organic matter content and enhance soil carbon sequestration.<sup>79</sup>

#### **2.2.4. Climate Benefits of Organic Agriculture**

Organic farming systems offer some of the best opportunities in agriculture to reduce GHG emissions and sequester carbon. Organic operations are prohibited from using synthetic fertilizers or pesticides and instead use less fossil fuel intensive methods for soil and pest management, many of which are described above. When evaluating the potential climate benefits of organic agriculture, it is important to consider the net effect of farming practices on soil carbon and the GHG emissions associated with both on-farm practices and the production and transportation of all inputs.

A review of literature by the United Nations Food and Agriculture Organization found that, when including on-farm energy use as well as embedded energy in farm inputs and the post-production handling, organic agriculture production uses 30 to 50 percent less energy than comparable conventional systems<sup>80</sup> and therefore has fewer associated GHG emissions. Results from a 22-year study in the U.S. found that organic corn systems use inputs with 28 to 32 percent less embedded fossil fuel energy than conventional systems.<sup>81</sup> A Canadian study modeled the energy demand and global warming potential of organic corn, canola, soy and wheat systems and found that on average organic production consumed 39 percent of the energy and generated 77 percent of the GHG emissions of their conventional counterparts.<sup>82</sup>

Several studies find that organic agriculture sequesters more carbon than conventional farming systems.<sup>83,84,85,86,87</sup> A United Nations Food and Agriculture Organization (FAO) literature review of eleven studies found that all of the eleven studies reported higher carbon content in organically managed soils compared to conventionally managed soils.<sup>88</sup>

A Central Valley study looking at alternative soil management practices for seven different crops found that organic farming systems sequestered the most carbon, followed by cover cropping, and then conservation tillage.<sup>89</sup> In a 12-year California study of organic farming practices, carbon sequestration was improved by 36 percent with the use of cover crops and animal manures even though the organic system used more tillage for cultivation compared to conventional systems.<sup>90</sup>

### **2.3. Preserving California Farmland**

California is losing farmland to development at an alarming rate—roughly 40,000 acres are lost each year.<sup>91</sup> This loss of California farmland limits opportunities to mitigate and adapt to climate change.<sup>92</sup> Compared to the dark surfaces of rooftops and pavement that absorb sunlight, farmland and rangeland increase the albedo effect—the ability to reflect sunlight and cool temperatures.<sup>93</sup> Moreover, protecting farmland around urban areas helps to limit sprawl and associated transportation-related GHG emissions.<sup>94</sup> Farmlands provide numerous additional benefits, including the ability to sequester carbon, preserve open space, absorb and filter water, and provide for a growing population.

## 2.4. Climate Change Adaptation

Climate change will bring inevitable changes that will require California agriculture to adapt to new precipitation patterns, new pests and more extreme temperatures and weather events.<sup>a</sup> There are many ways that conservation-oriented approaches can help agriculture reduce its vulnerabilities and enhance resilience to a changing climate.

For example, a recent review by University of California researchers<sup>95</sup> finds that alternative soil management practices—such as cover cropping, organic fertilizers and reduced tillage—have many benefits beyond reducing GHG emissions, including:

- Increased soil fertility
- Reduced soil erosion
- Improved water infiltration (which improves water conservation and limits the impacts of flooding)
- Decreased reliance on fossil-fuel-based fuels and inputs such as synthetic fertilizers (which also decreases cost)
- Increased habitat for beneficial insects (which reduces the need for pesticides)

A 22-year organic field study found that organic systems performed better in four out of five years of moderate drought by maintaining high levels of soil organic matter that helped conserve soil and water resources.<sup>96</sup> Improving soil organic matter increases soil fertility while also increasing the water retention capacity of soils, thereby reducing the impacts of droughts, as well as reducing the risk of floods.<sup>97,98,99</sup> Sustainable farming practices such as mulching and integrating perennial crops and trees onto farms also conserves soil moisture and reduces the damage from extreme weather events.

Diversified farming systems that incorporate crop rotations, multiple cultivars, and cover crops can not only protect and enhance the fertility of the soil, but also protect farms from yield losses or crop failures<sup>100</sup> that may increase because of changes in climate.

## 2.5. Summary

Farming systems that reduce the reliance on synthetic inputs, conserve natural resources and provide multiple environmental benefits offer promising opportunities within agriculture to mitigate and adapt to climate change. Understanding these opportunities within the California context of regional climates, soils and diverse ecosystems will best position the state's agriculture sector to tackle climate change and adapt to its impacts.

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<sup>a</sup> See the 2009 California Climate Adaptation Strategy report for more on how agriculture may adapt to a changing climate. <http://www.climatechange.ca.gov/adaptation>



### 3.

## Study Methodology

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We divided the analysis of the status of resources available for California agriculture to address climate change into three categories: research, technical assistance and financial incentives. Each plays an important part in realizing the opportunities within agriculture to shift towards farming systems that conserve natural resources, reduce GHG emissions, sequester carbon and support agriculture in adapting to a changing climate.

Outlined below is the methodology we used to identify relevant projects and programs in each category and the methodology for evaluating their relevance from a sustainable and organic agriculture perspective.



Illustration: Elayne Sears

## 3.1. Review of Scientific Research

The state and federally funded research projects consulted for this project conform to the following criteria:

- i. California-based research
- ii. Directly addressed mitigation and/or adaptation agricultural practices in relation to climate change
- iii. Funded or conducted since 2007

Although a wide variety of agricultural research projects may have some bearing on the responses of agricultural producers to climate change (e.g. projects studying irrigation efficiency, or projects looking at reducing synthetic inputs generally), the scope of the review was restricted to projects that explicitly framed their research questions in relation to climate change.

### 3.1.1. Identifying Research Studies

To identify relevant research studies, we reviewed grant programs and initiatives of the state and federal agencies involved in agriculture and climate change issues. We reviewed publicly available information, including project abstracts, program descriptions, open meetings and research reports.

Our state-level review began with the AB 32 Scoping Plan, which outlines the implementation strategies for achieving reductions of the state's GHG emissions to 1990 levels by 2020. The Scoping Plan activities for agriculture are fairly limited in number and scope, but it provides an overview of the state's priorities relative to climate change and agriculture. To find relevant state-funded research studies on agriculture and climate change, we searched websites of state agencies that are coordinating Scoping Plan activities related to agriculture, including the California Air Resources Board (CARB), the California Energy Commission (CEC), and the California Department of Food and Agriculture (CDFA). As part of this work, we reviewed the work of the state's Climate Action Team (CAT) Agriculture Working Group, including the CAT Near-term Implementation Plan (CATNIP) reports. We also spoke to agency staff and attended public meetings on agriculture Scoping Plan activities. And we reviewed CDFA's Specialty Crop Block Grant program, and we included relevant research projects funded by the Kearney Foundation of Soil Science of the University of California.

Federal research funding provides the bulk of publicly funded research on agriculture and climate change issues in California. To find relevant research studies, we searched the USDA Current Research Information System (CRIS), an online database of ongoing and recently completed projects in agriculture, food and nutrition and forestry. Projects listed in CRIS are sponsored or conducted by USDA research agencies, agricultural experiment stations, land grant universities, other cooperating state institutions and participants in National Institute of Food and Agriculture (NIFA) grant programs.

We searched the online database of the Sustainable Agriculture Research and Education (SARE) program of USDA. SARE has four grant categories: research and education, professional development, producer grants and on-farm research/partnerships. Only the research and education grants category included research projects relevant to our review. We also included the Conservation Innovation Grant program of Natural Resources Conservation Service (NRCS) in our review. Finally, we searched the online database of the National Science Foundation (NSF).

When searching public databases, the following search terms were used: California + any of these: *climate change, changing climate, global warming, greenhouse gas and carbon sequestration.*

As stated, the review was limited to publicly available information on state and federally funded research. Where feasible, we submitted Freedom of Information Act (FOIA) requests to acquire additional detail; however, in some cases we were still unable to obtain meaningful and comprehensive information. Where full project abstracts or reports were not available, we were forced to rely on brief program descriptions in our evaluation. In all cases, we looked for funding amounts in order to fully evaluate the scale and direction of public support; however, we were able to find funding levels in significantly fewer than half the projects reviewed and, therefore, we did not quantify our findings in terms of financial investments.

While we made every attempt to fully capture all relevant state and federally funded climate change and agriculture studies, because this information is not centrally compiled and catalogued, it is possible that our review overlooked some studies.

### 3.1.2. Timeframe

We reviewed state-funded research projects initiated between January 2007 and December 2010. The start date of January 2007 was chosen because it was the first year of implementation of AB 32, California's climate law. Until then, the state did not have a coordinated, interagency effort to reduce GHG emissions and address climate change impacts, and very little research relevant to the scope of this review was conducted. The CEC, through its PIER program, has funded climate change research in the state since 1998. However, in reviewing PIER-funded climate change and agriculture research, we found that prior to 2007, the vast majority of the agriculture-related projects focused on climate change impacts on agriculture or agricultural impacts on climate, and not how agriculture might reduce GHG emissions or adapt to climate change: we found only one PIER research project on agriculture mitigation and adaptation issues funded prior to 2007.

Since we are most interested in how agriculture might cope with climate change and reduce emissions or adapt to climate change, our review begins in 2007, the year these issues gained more state funding attention.

We used the same timeframe for our federal research review (January 2007 to December 2010). Prior to President Obama's administration coming to office in 2009, USDA, the primary public funding source for agricultural research in the country, did not have a focus on climate change research. Now, climate change is one of the top funding areas for the National Institute of Food and Agriculture of USDA, which hopefully will result in greater research attention on climate change issues for California agriculture.

### 3.1.3. Sustainability Indicators

Sustainable agriculture offers great promise in terms of climate change mitigation and adaptation strategies for agriculture, and warrants attention and resources to realize its potential (see Section Two). The precise meaning of the term "sustainability" is hotly contested, however, and in relation to agriculture there are myriad considerations and complexities.

To conduct the review, and in an attempt to characterize some core aspects of sustainability in agriculture, we used the following six indicators of sustainability to evaluate each study for their inclusion of sustainable agriculture practices and approaches.

1. **"Organic":** The studies were characterized for their inclusion of organic farming and ranching practices that prohibit the use of synthetic fertilizers and pesticides. Each study was assigned one of the following classifications: 1) Organic Focus—Studies that focus exclusively on organic farming research as it relates to climate change mitigation and adaptation; 2) Organic Component—Studies with organic farming systems included as a component of the study, often in comparison to conventional farming systems; and 3) No Organic Component — No inclusion of organic farming systems.



2. **“Integrated”**: The studies were characterized according to their inclusion of an integrated farming systems management approach that considers how the biological systems of a farm interact and affect its carbon footprint and/or its resilience. Such an approach relies not on technology or off-farm inputs as central to reducing GHG emissions or adapting to climate change, but rather takes a biological farming systems approach. Each study was characterized as including or not including an integrated farming systems approach.
3. **“Water and Energy Efficiency and Natural Resource Conservation”**: The studies were characterized for their inclusion of farm management practices to achieve water and energy use efficiency and/or natural resource conservation. Each study was classified either as including or not including water or energy efficiency or natural resource conservation practices.
4. **“Reduced Inputs”**: The studies were characterized for their inclusion of reduced farm inputs (e.g., chemical fertilizers, pesticides, animal feed). Each study was classified either as including or not including an examination of practices that emphasize reduced inputs.
5. **“Economic”**: The studies were characterized for their consideration of the economic impacts of the management practices examined (e.g. how changes in practices may impact profitability). Each study was classified either as including or not including economic impacts.
6. **“Social”**: The studies were characterized for their consideration of the social impacts of farming practices (e.g., how the adoption of a practice or set of practices affects the quality of life of the farmers, farm workers and/or community). Each study was classified either as including or not including social impacts.

### 3.1.4. Research Studies Not Examined

For the purposes of this review, we were interested exclusively in climate change mitigation and/or adaptation research studies dealing with the practice of agriculture. That is, we were concerned with research looking at *how* growers produce food and fiber, and the ways agriculture can reduce GHG emissions, sequester carbon or adapt to altered climate patterns.

We identified additional studies that dealt with the climate change/agriculture interface, but which we felt were functionally separate topics that could not be evaluated using indicators of sustainability. These studies, a list of which is provided in Appendix B, included:

- **Impacts.** These studies examined either the impact of climate change on agriculture, or agriculture’s contribution to climate change, including how biological functions on the farm may contribute to climate change (e.g. soil carbon cycling mechanisms). While these provide valuable baselines for the role agriculture plays in climate change, or for understanding the needs of California agriculture in coping with climate change, they did not provide information that will help growers alter production practices to mitigate and/or adapt to climate change, which was the focus of this review.
- **On-farm renewable energy generation.** Examining opportunities for on-farm renewable energy production can help agriculture reduce its own carbon footprint and serve as a source for renewable energy generally. However, because there is not necessarily a relationship between renewable energy generation and the application of sustainable agriculture practices in a given operation, we did not analyze these studies for their contribution to understanding agricultural adaptation and/or mitigation.
- **Biofuels production.** We did not include in our analysis any research studies focused on biofuels production. This research is largely driven by the desire to find new low-carbon fuel sources for transportation, and not by our primary concerns—i.e., studies that suggest how agriculture might cope with climate change. Moreover, important questions have been raised about the sustainability of biofuels production, including competing land uses between food and fuel production. Addressing these important questions, while important, goes beyond the scope of this review.

## 3.2. Resources for Technical Assistance

Technical service providers who provide advice and expertise on a host of issues for California farmers and ranchers—including pest and soil management, crop rotations and on-farm renewable energy generation—are vital for translating and communicating the latest science to match the experiences and needs of agricultural producers. Technical service providers will play an evolving and important role in the years to come as climate change brings new production challenges for the state’s farmers and ranchers.

Our review focused on the status of publicly funded technical service providers who are connected either to the land grant university system or USDA and, thus, have access to science-based technical information. To understand the state of agricultural technical assistance in California, we spoke to current and retired state and federal staff, reviewed newspaper articles and attended government agency meetings.

## 3.3. Resources for Financial Incentives

States like Wisconsin, Iowa and Pennsylvania offer direct financial incentives to farmers and ranchers to use conservation measures on their operations. We wanted to know to what extent California producers have access to similar direct incentives. We did not consider in our review of incentive programs, granting programs from the state to local governments or private entities to support conservation efforts in their regions. While important, we are concerned with efforts by the state to provide incentives for individual producers to directly alter their production practices to achieve conservation objectives.

To analyze the status of California’s incentive programs, we reviewed both state and federally funded on-farm conservation incentives programs available to California producers. In reviewing possible state incentives, we reviewed the websites of state departments and agencies involved in agriculture: CDFA, CARB, CEC and the Department of Conservation (DOC). We also reviewed the status of USDA conservation program funding in California.

## 4.

# Findings

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Here we summarize the results of our evaluation of the research, technical assistance and financial incentives available to support California agriculture in addressing the fundamental challenges of climate change.



## 4.1. Status of Scientific Research

In our review of state and federally funded research, we identified 115 California agriculture and climate change research projects initiated since 2007. Of these, we found surprisingly few California agriculture-specific climate change mitigation and adaptation research projects. As we describe Section Three, these are studies concerned with the practice of farming. They seek to understand how changes in production practices can reduce GHG emissions, sequester atmospheric carbon in soils or woody biomass and reduce the vulnerability of agriculture to climate change effects.

As shown in Table 2, 39 of 115 studies examined how California agriculture may mitigate or adapt to climate change (listed in Appendix A). The 74 remaining studies (summarized in Appendix B) examined a range of other issues, such as renewable energy production, impacts of climate change on agriculture, soil carbon cycling, agriculture's contribution to GHG emissions, and biofuels production. While important, these studies were not the focus of our review.

**Table 2. Summary of Agriculture and Climate Change Studies**

	Total Number	Research Focus				
		Adaptation and/or Mitigation <sup>a</sup>	Renewable Energy	Impacts	Biofuels	Planning Grant
State Funded	46	12	4	27	3	0
Federally Funded	69	27	3	25	13	1
TOTAL STUDIES	115	39	7	52	16	1

<sup>a</sup> These are the studies assessed in this review. See Appendix A for a listing of these studies. Appendix B lists all other studies.

### 4.1.1. Studies Assessment

Below we discuss our assessment of the 12 state-funded and 27 federally-funded agriculture climate change mitigation and adaptation research projects. We assessed the projects on the five indicators of sustainability, as described in Section Three. They are:

- Organic Systems
- Integrated Biological Systems
- Water/Energy Efficiency and Natural Resource Conservation
- Reduced Farm Inputs
- Economic Impacts
- Social Impacts

#### Organic Systems Indicator

We found that little focus has been given to studies of organic farming systems and their role in climate change mitigation or adaptation. Twenty-seven of the 39 studies (69 percent) did not include an organic farming component in their research design. Eight studies included organically managed fields as a component of the research study, often comparing conventionally managed production with the organic systems.

Only four of the 39 climate change mitigation and adaptation studies had a primary focus on organic farming systems, all of which were federally funded. The four studies were conducted on organically managed fields and investigated questions of carbon sequestration, nutrient cycling and related climate change mitigation and adaptation production activities. An example of a strong

organic focus study, funded by USDA, is a project entitled *Researcher and Farmer Innovation to Increase Nutrient Cycling on Organic Farms*, which was conducted on organic farms with the goal of developing more sophisticated tools to map nitrogen availability, identify methods to increase crop N uptake, and provide other environmental benefits, including climate benefits.

**Table 3. Results for Organic Systems Indicator**

	State-Funded	Federally Funded	Total
Organic focus	0	4	4
Organic component	5	3	8
No organic component	7	20	27
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

### Integrated Biological Systems Indicator

Nineteen studies (48 percent) included an integrated farming systems component, examining multiple aspects of biological approaches to farm management for their impact on reducing GHG emissions, sequestering carbon and/or adapting to climate change. Two state-funded studies, *Assessment of Greenhouse Gas Mitigation in California Agricultural Soils* and *Potential for Adaptation to Climate Change in an Agricultural Landscape in the Central Valley of California*, provide the best examples of research that approaches the question of agriculture's role in climate change mitigation or adaptation from an integrated farming perspective, looking at the farm as a complex ecosystem.

The majority of studies did not rank well in this category because they either looked at farming practices in isolation from one another (e.g. fertilizer use) or focused exclusively on technological solutions to mitigation or adaptation (e.g. more efficient irrigation equipment).

**Table 4. Results for Integrated Biological Systems Indicator**

	State-Funded	Federally Funded	Total
Integrated farming systems—Included	7	12	19
Integrated farming systems—Not included	5	15	20
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

### Water and Energy Efficiency and Natural Resource Conservation Indicator

Water and energy use efficiency and natural resource conservation, generally, in agriculture can offer important climate change mitigation benefits by reducing GHG emissions associated with the movement of water and fossil energy use. There are also climate change adaptation benefits with efficiency and conservation measures, which will be especially important to realize as water resources become more constrained in future years. We wanted to know to what extent researchers were exploring these options when pursuing questions related to agriculture's response to climate change.

We found 13 studies (33 percent), most of which were federally funded, that included some aspect of water and energy use efficiency and/or natural resource conservation (e.g. increased biodiversity).

**Table 5. Results for Water/Energy Efficiency and Natural Resource Conservation Indicator**

	State-Funded	Federally Funded	Total
Water and energy efficiency and natural resource conservation—Included	3	10	13
Water and energy efficiency and natural resource conservation—Not Included	9	17	26
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

### Reduced Farm Inputs Indicator

Twelve of the studies (31 percent) included a focus on reducing farm inputs (e.g. fertilizers, pesticides or animal feed) to reduce GHG emissions. We had anticipated finding a significant number of studies with this indicator, given that it does not require fundamental change in the farming system; however, less than a third of the projects included a focus on reduced farm inputs.

**Table 6. Results for Reduced Inputs Indicator**

	State-Funded	Federally Funded	Total
Reduced inputs approach—Included	5	7	12
Reduced inputs approach—Not included	7	20	27
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

### Economic Indicator

Producers will need to know to what extent yields and profitability are affected by changes in production practices to provide climate benefits. However, we found only 16 studies (41 percent) included an assessment of the economic impacts of mitigation and/or adaptation strategies.

**Table 7. Results for Economic Impacts Indicators**

	State-Funded	Federally Funded	Total
Economic impacts—Included	4	12	16
Economic impacts—Not included	8	15	23
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

### Social Impacts Indicators

We found only one state-funded study and just four federally funded studies that considered the social implications of altering agricultural practices to reduce GHG emissions or adapt to a changing climate.

**Table 8. Results for Social Impacts Indicators**

	State-Funded	Federally Funded	Total
Social impacts—Included	1	4	6
Social impacts—Not included	11	23	33
<b>TOTAL STUDIES</b>	<b>12</b>	<b>27</b>	<b>39</b>

## 4.1.2. Summary of Research Findings

Given California's focus on climate change issues with the passage of AB 32 and the Obama administration's focus on climate change issues nationally, we found surprisingly few research studies focused on questions relating to how California agriculture can begin to grapple with climate change—only 39 state and federally-funded studies initiated since 2007.

Relatively few studies included a focus on organic and sustainable farming systems. Table 9 provides a summary of our analysis.

**Table 9: Summary of Findings for Sustainability Indicators**

Indicator	Number of Studies	Percent of Total Studies
Organic focus	4	10%
Organic component	8	21%
Integrated farming systems—Included	19	49%
Water and energy efficiency and natural resource conservation—Included	13	33%
Reduced inputs approach—Included	12	31%
Economic impacts—Included	16	41%
Social impacts—Included	6	15%

Given agriculture’s unique vulnerabilities to changing climate patterns and constrained natural resources, research is needed to understand the opportunities and challenges for agriculture to address climate change. Moreover, California’s unique cropping patterns, soils and climate patterns warrant state- and cropping-system-specific research.

## AB 32 Implementation

### AB 32 Scoping Plan

AB 32 implementation is guided by a Scoping Plan that details how the state of California will meet its GHG emissions targets. The development of the Scoping Plan was informed by the Economic and Technology Advancement Advisory Committee (ETAAC), a citizen-led advisory group. Also, a number of interagency Climate Action Teams were established for various sectors, including one for agriculture (AgCAT).

The agriculture sector report of ETAAC recommended seven possible farm-level management strategies to reduce GHG emissions. Their strategies included renewable energy generation, riparian restoration and plantings, soil management to sequester carbon, and more. The agriculture sector report of AgCAT also proposed several strategies to reduce agricultural GHG emissions. Together, ETAAC and AgCAT found that, through a variety of practices, California agriculture may reduce GHG emissions between 9.1 to 16.7 million metric tons of CO<sub>2</sub> emissions (MMTCO<sub>2</sub>e), representing a third to half of the projected agricultural GHG emissions in 2020.<sup>101,102</sup> However, little of what was detailed in ETAAC and AgCAT reports was included in the final Scoping Plan. Overall, agriculture receives little attention in the Scoping Plan, and the sustainable and organic agriculture perspective is largely absent.

### Status of Scoping Plan Action

We gathered information on the status of the Scoping Plan activities pertaining to agriculture from various state agency websites (CDFA, CARB, CEC), and by attending meetings and speaking with state agency staff. We summarize the status here, including an evaluation of the inclusion of sustainable and organic agriculture methods.

The four primary Scoping Plan activities for agriculture currently underway are:

#### a) Nitrous oxide emissions study

CARB, CDFA and CEC are jointly funding research to establish baseline nitrous oxide (N<sub>2</sub>O) emissions from agriculture. Nitrous oxide is 300 times more potent than CO<sub>2</sub>, and agriculture is a significant source. Over a period of three years, three UC Davis researchers and one Fresno State researcher are conducting N<sub>2</sub>O emissions analyses in multiple cropping systems including tomatoes, almonds, wine grapes, walnuts, alfalfa, silage, cotton, rice, lettuce and wheat. In several instances more than one field of a crop type is being monitored for N<sub>2</sub>O



emissions. Only one study field, a walnut orchard, is under organic farming management. One researcher is also studying N<sub>2</sub>O emissions from tomatoes under reduced tillage and drip irrigation management. All other study fields are under conventional management. Baseline studies of N<sub>2</sub>O emissions from dairy manure applied on fields are also being conducted, along with composting emissions studies. A biochar study looking at its applications to fields and its implications for emissions was also recently funded by CEC.

#### **b) Renewable energy workshops for producers**

CDFA is leading the effort to host workshops for producers to promote their adoption of renewable energy technologies. However, despite repeated requests to obtain information, CDFA staff was unable to confirm if workshops have been held or what information is being offered.

#### **c) Addressing regulatory and technological barriers to anaerobic digesters**

Anaerobic digesters are used primarily on dairy farms to capture methane emitted from manure lagoons, which would otherwise be released as a potent GHG. The digesters capture the methane gas and use it to produce energy.

CDFA, working with CARB and local agencies, is helping to lead the effort to address regulatory, financial and technological barriers to the development of methane digesters on dairies in the Central Valley. In February 2010, CDFA signed a memorandum of understanding with a digester developer to establish three methane digester pilot projects. Additionally, in December 2010, the Central Valley Water Resources Control Board adopted a programmatic EIR to ease permitting of digester development in the Central Valley. Finally, CARB approved a methane digester protocol for use in the carbon market once the AB 32 cap-and-trade program is fully implemented in 2012.

Despite the coordinated agency efforts on methane digesters, questions remain about the economics (digester systems may cost hundreds of thousands of dollars or more to establish) and the technical barriers to limiting impacts on air quality in the San Joaquin Valley.

#### **d) Agricultural offset protocols**

As part of the cap-and-trade program, CARB is developing protocols for agricultural activities that reduce GHG emissions and may become eligible for credits on the carbon market. Proposed offset protocols are reviewed by CARB staff, open to public comment and ultimately must be approved by the CARB board. Currently, only one agriculture-related offset protocol, methane digesters for dairies, has been approved for use in the future California carbon market.

The Climate Action Reserve (CAR), a private nonprofit organization, recently created stakeholder groups to guide the development of three additional agricultural protocols, including reduced methane emissions in rice production; cropland management; and nutrient management. These protocols will be used on the existing voluntary carbon market for participants in CAR's carbon market program, and will inform the protocols developed and adopted by CARB.

#### **Missed Opportunity**

To understand and realize the climate change mitigation and adaptation opportunities in the agriculture sector, a whole farm systems approach must be employed, rather than the piecemeal approach CARB and other state agencies are currently using, looking at each practice (e.g., methane digesters, N<sub>2</sub>O emissions) in isolation. Without a whole farm systems approach, there is the risk that incentives will be put in place for agricultural practices that may not ultimately reduce agriculture's overall carbon footprint.

Moreover, the lack of attention to sustainable and organic farming systems approaches to mitigation strategies in AB 32 implementation represents a missed opportunity. Many organic and sustainable agriculture practices not only reduce GHG emissions, but also provide multiple environmental benefits, such as improved air and water quality and enhanced wildlife habitat.



## 4.2. Review of Resources for Technical Assistance

It is not sufficient only to study how California agriculture might cope with a changing climate and help mitigate it; research findings must then be translated into on-the-ground, practical assistance for farmers and ranchers. Access to technical expertise from well-trained farm advisors allows growers to avoid re-inventing the wheel and access science-based information that they may consider applying to their operations.

Unfortunately, our current system of state technical assistance is inadequate to meet the significant challenges of climate change. Budget cuts have eliminated staff and offices, including the UC Small Farm Center, and scaled back others like the UC Sustainable Agriculture Research and Education Program (SAREP).

Some may argue that the private sector can fill the gaps left by government budget cuts and shifting priorities. While there is undoubtedly a role for the private sector in providing climate solutions for agriculture, there is also a need for land-grant universities, publicly funded competitive grants programs and other mechanisms funded by and under the authority of institutions with a public benefits mandate and mission. Moreover, the challenges of climate change require agricultural solutions that are based in science and take a whole farm systems approach, which often goes beyond the training and scope of most private farm consultants.

What follows is a review the state of the technical assistance for California's agricultural producers.

### 4.2.1. University of California Cooperative Extension

For over 100 years the primary source for grower technical assistance in the state has been the University of California Cooperative Extension Service. Established in 1897, the mission of UC Cooperative Extension is to bring the university and its research to the state's agricultural producers.

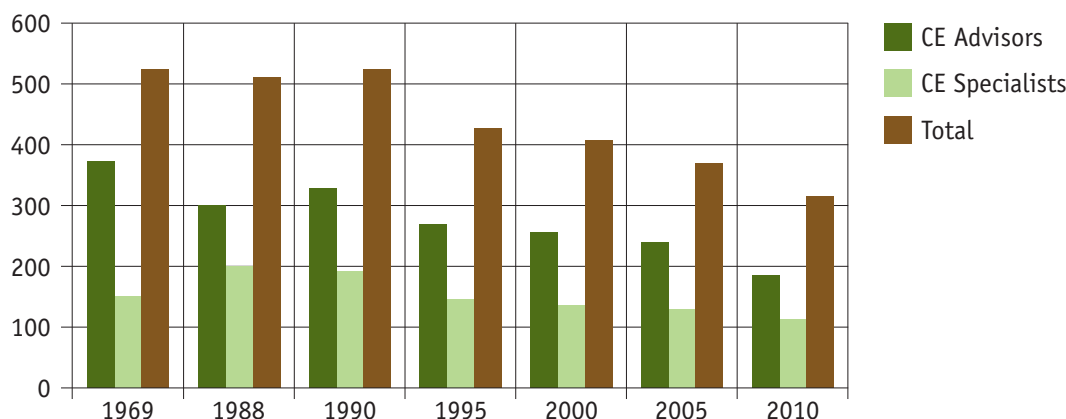
Extension farm advisors work with producers in their counties to conduct research, host on-farm demonstrations and provide technical expertise on a host of issues. Academic Extension specialists are issue experts, and work with the Cooperative Extension farm advisors and university researchers to develop research and education programming that reflects both the needs of the agricultural community and the expertise of the university.

However, this bridge between the university and the agriculture community has weakened in recent years. Budget cuts over the past decades have left the Extension system with greatly diminished staff levels. The number of on-farm advisors peaked in 1969 at 380 advisors, and the number of Extension specialists peaked at 208 specialists in 1988 (see Figure 4). Today, there are only 200 Extension on-farm advisors and 119 specialists, down 40 percent since the early 1990s.

In comparison, Texas, second in the country after California in agricultural product sales, has 900 county-based Extension specialists. While they also face budget cuts that threaten to reduce staffing levels, Texas Extension Service remains much more robust than California Cooperative Extension.<sup>103</sup>

Shifting university priorities have also limited the outreach capacity of Cooperative Extension in the state over the years. In the late 1980s academic Extension specialists were moved from the Agricultural Experiment Station and other Extension offices to UC academic departments. The motivation for the structural changes was to better integrate Extension activities within existing academic departments. However, Extension specialists found themselves under the same reward system as other academics, having their tenure status largely determined by the number of published, primary research articles and books—i.e., the “publish or perish” system of academia—and not by the success of their outreach work to the agricultural community, which had been the foundation of Extension activities. Consequently, the amount of time an academic Extension specialist is able to devote to bringing university research to the state's agricultural community has declined over time, as they must now devote substantial time to conducting and publishing research, and in some cases finding their own funding to adequately cover their program costs.

**Figure 4. Trend in Extension staff positions 1969-2010**



Source: UC Cooperative Extension October 2010. Email communication.

## History of Sustainable Agriculture Research and Education at the University of California

Following World War II, Cooperative Extension staff throughout the United States embraced a move toward industrial farming, dependent on the use of synthetic pesticides, fertilizers, irrigation and hybrid seeds, as a way to boost crop yields and increase profits. Not all within the agricultural community embraced this move, however. In the 1970s the modern organic agriculture movement was born, and California was at the center of it, developing farming systems that relied on biological systems for soil fertility and pest control rather than the use of synthetic chemical inputs.

In the 1980s, organic and sustainable agriculture advocates in California pushed for greater university research and education programming that addressed their priorities. In the mid-1980s, State Senator Nick Petris, Chair of the Education Committee's budget subcommittee, held hearings around California on the state of sustainable and organic agriculture research at the University of California and the needs of the state's growers. In 1986 Senator Petris sponsored legislation, SB 872, which created the UC Sustainable Agriculture Research and Education Program (SAREP).<sup>104</sup> The legislation created an educational home and mission for sustainable agriculture research and education within the UC system.

SAREP is a statewide program, and its programs include providing competitive grants for sustainable agriculture research priorities, developing and distributing sustainable agriculture information to producers and educators, and establishing long-term farmland research sites to study sustainable farming systems.

Today, SAREP is a program of the Agriculture Sustainability Institute (ASI) at UC Davis. University budget cuts and shifts in priority have meant that some of SAREP's programs were put on hold during the transition to a new institutional management arrangement with ASI. The core budget currently supports six full-time equivalent staff, with additional six short-term staff funded by external grants at the time of this writing. Funding cuts resulted in an 18-month gap in publications and a three-year gap in competitive sustainable agriculture research grants; a new round of funding was announced in the fall of 2010.

Additional university budget cuts in 2009-10, which included a 20 percent cut in permanent funding for SAREP, raise concerns about future programming and the ability of SAREP to provide ongoing competitive research grants in sustainable agriculture. Moreover, ASI, SAREP's new institutional home, does not have an explicit emphasis on organic farming systems research and education. This creates uncertainty about the continued role of organic agriculture research and education in SAREP, where it was a significant focus from 1999 to 2004.

#### 4.2.2. Resource Conservation Districts

Formerly known as Soil Conservation Districts, the Resource Conservation Districts (RCDs) were formed by the FDR administration in response to the soil losses of the 1930s Dust Bowl crisis that resulted in the significant dislocation of Midwest farmers. Prior to their creation, farmers did not have access to technical expertise on soil conservation issues. The RCDs continue today and provide important conservation technical expertise for farmers and ranchers throughout the country and in California. RCDs work in cooperation with Natural Resources Conservation Service of USDA, described below.

The California RCDs were formed in the 1940s and now number 103 districts and 12 tribal RCDs. RCDs have since expanded from their early work on soil conservation to work on a variety of conservation issues, including regional watershed planning and energy efficiency outreach to producers.

Like Cooperative Extension, state and local government budget cuts have hurt staffing levels of the RCDs. The California Department of Conservation, which provides training and funding for the RCDs, ended its RCD grant program in 2003.<sup>b</sup> When the current state fiscal crisis began in 2008/2009 and funding for state contractors was put on hold until a final budget was passed, many of the RCDs faced staff layoffs. Today, budget cuts have left some RCDs with greatly reduced staffing levels and programming, leaving them trying to rebuild and find new funding sources to maintain their programming and technical expertise.

#### 4.2.3. USDA Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is the conservation arm of USDA. It provides conservation planning and technical assistance for producers and administers farm bill programs that provide financial incentives for on-farm conservation practices.

California NRCS currently has roughly 400 state and regional specialists and county-level conservation staff. While farm bill conservation program funding in the state has risen in recent years—increasing by 200 percent from 2005 to 2010—the number of California NRCS staff has declined by 7 percent in that time from 435 to 405 people.<sup>105</sup> To keep up with the demands of implementing farm bill programs, county-level NRCS staff now spend the bulk of their time in their offices preparing farm bill program contracts with producers, resulting in limited time in the field for providing conservation planning and technical assistance for growers.

To their credit, the leadership of California NRCS has recognized the problem, and they are attempting to streamline the contracting process for farm bill programs to allow their staff more time to work directly with producers on conservation planning. But the problem largely rests with Congress, which has refused over the years to increase the amount of farm bill appropriations that may be used toward increasing USDA staffing to implement conservation programs. Consequently, some of the state's best agronomists find themselves spending more time completing paperwork and less time out in field with the state's farmers and ranchers.

#### 4.2.4. Summary of Technical Assistance Findings

Budget cuts and shifting priorities have scaled back the state's system of technical assistance for farmers and ranchers at a time when the issues facing them are more complex than ever before. There is interest among policymakers and industry leaders in supporting California agriculture to conserve water, sequester atmospheric carbon, produce renewable energy and provide multiple environmental benefits while producing healthy, sustainable food and fiber. However, even the current combined resources of the University of California, the Resource Conservation Districts and NRCS are inadequate for meeting the technical assistance needs of the state's 81,500 farmers and ranchers.

We must reinvigorate public investment in agricultural technical assistance and provide the technical training necessary for farm advisors to support California's farmers and ranchers in meeting the challenges of the 21<sup>st</sup> century.

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<sup>b</sup> DOC maintains a part-time staff person who coordinates activities with the California Association of RCDs.

## 4.3. Review of Resources for On-Farm Incentives

Climate change presents many formidable challenges for California agriculture. The state has much to gain by promoting a land stewardship ethic that conserves natural resources, restores ecosystems and supports resilience in the face of climate change. Here we review the status of California conservation incentive programs from state and federal sources.

### 4.3.1. State Conservation Incentives

In our review of state incentive programs for agricultural producers, we were concerned with access to direct incentives for agricultural producers. California has grant programs for local government and nonprofit entities to support conservation activities. For example, the Department of Water Resources' Integrated Regional Water Management Grants program provides grants for important regional activities to support water resource management, and the Department of Conservation's California Farmland Conservancy Program provides grants for land trusts to support conservation easements on farmland. While these programs are important to supporting the state's conservation efforts, they do not provide the direct incentive to support individual farmers and ranchers in overcoming barriers to conservation practices, such as high transition costs and yield losses in the short term.

State programs to support irrigation and energy use efficiencies in agriculture have led to savings, according to various university and state agency experts we consulted. But promotion of a diversity of on-farm conservation practices—from soil and water conservation to riparian restoration and biological farming practices and beyond—through direct incentives, does not exist at the state level. Yet there is producer demand and a growing need for these programs, as we describe below.

### 4.3.2. Farm Bill Conservation Programs

The USDA is the largest source of funding for agriculture conservation activities in the country. Conservation programs vary in design, but all seek to incentivize conservation through direct payment to producers in return for their use of stewardship practices.

The 2008 Farm Bill greatly expanded funding for agricultural conservation programs, including creating two new programs, the Conservation Stewardship Program (CSP) and the Organic Transitions Program within the Environmental Quality Incentives Program (EQIP). The CSP takes a whole-farm approach to conservation, rewarding producers for existing conservation activities and promoting additional conservation. EQIP, the largest funding source for on-farm conservation activities, supports a variety of activities, including conversion to organic farming and practices that improve air and water quality and enhance wildlife habitat.

For our review of federal conservation programming available to California producers, we examined California NRCS data on current demands for the programs and available funding. Demand for these conservation programs continues to exceed current funding levels.

In 2009, 70 percent of the California farmers and ranchers who applied for USDA farm bill conservation programs were denied because of a lack of funding.<sup>106</sup> Similarly, in 2010, demand among California producers for USDA conservation incentives programs is exceeding current funding levels (see Table 10). In Fiscal Year 2010, California NRCS received 7,217 applications to 10 programs, for an estimated need of more than \$307 million. NRCS funded 44.5 percent of the applications (3,212).

In March 2010, a coalition of agriculture trade groups, sustainable agriculture and family farm organizations and environmentalists from California called on Congress to protect USDA conservation programs from threatened budget cuts.<sup>c</sup> To date, conservation programs have largely been spared congressional cuts, but pressure on Farm Bill conservation funding will likely increase as Congress begins 2012 Farm Bill negotiations. Moves to cut deficit spending and competing federal priorities will put budget pressure on conservation programs that do not have baseline funding in the Farm Bill.

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<sup>c</sup> For more on this topic, see: [http://foodsystemalliance.org/crae/category/farm\\_bill](http://foodsystemalliance.org/crae/category/farm_bill)

**Table 10: Status of USDA NRCS Farm Bill Conservation Program Funding for FY 2010**

The following table summarizes the funding received by California producers for Farm Bill funded conservation programs during fiscal year 2010.

Program	Applications Received	Number of Contracts Obligated (% of applications received)	Acres Enrolled	Total Allocated to CA NRCS	Estimated Amount Requested	Total Obligated by CA NRCS
Environmental Quality Incentives Program (EQIP)	5,461	1,973 (36%)	1,012,409	\$75.2 million	> \$200 million	\$75 million
Agricultural Water Enhancement Program (AWEP)	1,048	448 (43%)	80,419	\$21.15 million	> \$28 million	\$21.1million
Wildlife Habitat Incentive Program (WHIP)	94	36 (38%)	54,778	\$2.3 million	> \$3 million	\$2.3 million
Conservation Security Program (CSP)—2002 Farm Bill	No longer enrolling	387	n/a	No longer enrolling	No longer enrolling	\$4,147,654 in FY 2010 payments
Conservation Stewardship Program (CSP)—2008 Farm Bill	545	337 (62%)	709,977	\$6.3 million	> \$6.4 million	\$5.9 million
Wetlands Reserve Program (WRP)	30	13 (43%)	4,462	\$22.5 million	> \$35 million	\$22.5 (includes Grazing Rights Pilot)
Wetlands Reserve Program (WRP)—Grazing Reserve Right Pilot	1	1 (100%)	3,885	Included within CA WRP	> \$8.7 million	\$8.7 million (included in WRP total)
Emergency Watershed Protection Program FloodPlain Easements (EWPP)	5	5 (100%)	922	\$4.5 million	> \$4.2 million	\$4.3 million
Farm and Ranch Land Protection Program (FRLPP)	22	8 (36%)	3,950	\$5 million	> \$17 million	\$5 million
Grassland Reserve Program (GRP)	6	3 (50%)	4,016	\$1.9 million	\$2.5 million	\$1.9 million
Healthy Forests Reserve Program (HFRP)	5	1 (20%)	3,640	\$600,000	\$3 million	\$600,000
<b>TOTAL</b>	<b>7,217</b>	<b>3,212 (44.5%)</b>	<b>1,878,458</b>	<b>\$139.45 million</b>	<b>\$307.8 million</b>	<b>\$151.45 million</b>

Source: California NRCS, USDA

### 4.3.3. Carbon Market

California will launch its carbon market in January 2012 as part of the state's cap-and-trade program under AB 32. The proponents of the carbon market promise that agricultural producers will be able to sell credits for their climate-mitigating practices on the carbon market and reap financial rewards for their conservation activities.

However, we cannot rely entirely on future carbon markets to incentivize California agriculture in addressing climate change. The Chicago Climate Exchange (CCX) halted trading of carbon credits in 2010 due to a lack of congressional mandate for a mandatory carbon trading program and declining demand for voluntary carbon credits. Nonetheless, CCX offers important lessons as we move forward in addressing climate change mitigation in agriculture.

The offset protocols developed for CCX were heavily biased toward rewarding agricultural practices, such as conservation tillage, that benefited Midwest producers but were not effective for reducing emissions and sequestering soil carbon in the arid West. Furthermore, the marketplace tends toward simplified approaches to agricultural GHG mitigation—rewarding single practices rather than whole farming systems—which may not lead to overall GHG emission reductions, as discussed above.

The carbon market also may hurt early adopters of conservation measure. The carbon market will prohibit the entry into the market of early adopters of conservation measures because their good stewardship activities began before the carbon market was established; thus, their conservation activities are considered part of the baseline of emissions. Therefore, longtime conservation-minded producers may find their neighbors or marketplace competitors receiving payments for activities they themselves have long employed, but for which they are nonetheless ineligible to receive payments, putting them at financial disadvantage.

Moreover, the carbon market will not address the important need of supporting climate change adaptation activities in California agriculture, including on-farm water conservation activities, new crop varieties and more.

Finally, it is likely that few California farmers and ranchers will benefit from the carbon market as long as CARB insists that offset credits cannot be limited to California, but eventually will be bought and sold from other states and countries.

While carbon markets may play a limited role in California agriculture or other agricultural regions of the country, the potential for achieving significant mitigation benefits are not likely to be met with this mechanism alone, and programs to support on-farm conservation must be developed in the state.

### 4.3.4. Summary of Findings for On-Farm Incentives

Unlike other leading agricultural states such as Minnesota<sup>d</sup> and Wisconsin,<sup>e</sup> California does little to reward agricultural land stewardship. Despite the significant footprint of California agriculture and its impact on the state's environment and economy, state agricultural policy has not kept pace with what is needed to promote natural resource conservation in agriculture. Instead, California farmers and ranchers must rely upon federal farm bill conservation programs, which are inadequately funded and chronically face potential congressional budget cuts.

Transitioning to farming and ranching practices that have climate benefits and provide greater resilience to the coming impacts of climate change will present growers with new costs and risks. Thus, the state must consider how, as it has done with renewable energy, to incentivize agricultural conservation efforts that promote land stewardship, provide multiple environmental and health benefits and maintain a viable agricultural economy for decades to come.

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<sup>d</sup> For more on the Minnesota program, see: <http://www.mda.state.mn.us/esap>

<sup>e</sup> For more on the Wisconsin program, see: <http://datcp.state.wi.us/arm/agriculture/land-water/grazergrant/index.jsp> and <http://datcp.state.wi.us/mktg/business/marketing/val-add/directmktg/blbw/index.jsp>



## 5.

# Conclusions and Recommendations

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Agriculture is unlike any other sector of our economy and society. Based on the land, dependent on weather and the availability of natural resources, agriculture provides for one of our most basic needs: food. And as the country's leading agricultural producer, the reach of California agriculture is profound.

Climate change scenarios for the state suggest that we must take action now to limit greenhouse gas emissions and avoid the worst impacts of climate change while preparing our farmers and ranchers for inevitable climatic changes.



California is leading the country in its efforts to tackle the significant challenges of climate change. Yet as our review finds, California lacks the resources and the attention needed to help the state's farmers and ranchers address agriculture's unique vulnerabilities to climate change.

California has gone a long way to understand how climate change may impact the state's agriculture. But too few research studies have been done on how agriculture might respond effectively to reduce greenhouse gas emissions, sequester carbon and adapt to a changing climate. And even fewer studies take a sustainable and organic agricultural perspective. Moreover, the state's ability to provide technical assistance for farmers and ranchers is woefully inadequate to meet the complex challenges of climate change, since decades of budget cuts have cut staffing levels and eliminated programs.

California is an innovator in environmental policy that has led to the development of the clean energy and tech industries. But the state is behind the times when it comes to innovative agricultural policy.

Other agricultural states incentivize on-farm conservation measures that promote environmental stewardship and on-farm renewable energy. In contrast, the state of California lacks programs to support agricultural conservation, and barriers to on-farm renewable energy still exist. This is despite farmer and rancher demands for conservation programs, which the over-subscribed USDA conservation programs cannot currently meet.

California agriculture has unique climate change solutions to offer, but the state is failing to realize those solutions. California's governor, legislature and state agencies must act now to maintain a viable and sustainable agriculture in the face of a changing climate. And in these times of deep fiscal crisis for the state, California will have to look to new funding sources and shift existing resources to meet the challenges of climate change for California agriculture.

## 5.1 Recommendations

Governor Jerry Brown, the legislature and state agencies must take the following steps to move California's agricultural system closer to meeting the challenges of climate change:

### #1: Invest in California Agriculture

- Invest a portion of cap-and-trade auction revenue in research and demonstration, technical assistance and financial incentives for farmers and ranchers to adopt practices, technologies and farming systems that reduce GHG emissions, sequester carbon and adapt to climate change while providing environmental co-benefits such as improved air quality, water conservation and increased wildlife habitat.
- To oversee the implementation of this grants program, form an advisory committee made up of California researchers, agricultural producers, processors, nonprofit representatives and state and federal agency representatives with expertise in climate change and agriculture issues.

### #2: Prioritize Whole Systems and Participatory Research

- Research that takes into account whole farm systems should be emphasized and sustainable and organic farming systems approaches should be included in future research projects.
- Researchers who work directly with producers to conduct their research should be especially encouraged.

### #3: Build Bridges Between Researchers and Growers

- The state should re-invest in UC Cooperative Extension and Resource Conservation Districts with the eventual goal of returning to early 1990s staffing levels.
- Given the complexities of climate change, new and on-going training opportunities for farm advisors and specialists will be needed.



- Re-investment in the UC Sustainable Agriculture Research and Education Program (SAREP) is also needed to provide a hub for long-term farming research trials ongoing sustainable agriculture research and demonstration grants and relevant educational programming for producers and technical service providers.
- As state budget cuts threaten the ongoing viability of UC Cooperative Extension, these efforts should be funded by cap-and-trade revenue.

#### **#4: Support Stewardship**

- CDFA's Office of Agricultural and Environmental Stewardship (OAES), eliminated in 2009, should be reestablished and include new staff with climate change expertise. This office would build support for agricultural conservation practices among urban constituents and enhance understanding and cooperation with environmental and food advocates.

#### **#5: Develop Conservation Incentives**

- California can learn from other states like Wisconsin, Minnesota, Iowa and Pennsylvania that have developed direct producer incentives to support conservation goals.
- A reestablished OAES at CDFA should work with agency partners to develop a climate-oriented agricultural conservation incentive program, funded by cap-and-trade revenue.

#### **#6: Comprehensively Address Agricultural Adaptation to Climate Change**

- Create an Office of Climate Change Adaptation with an Agriculture Division.
- The office should be housed in either the Natural Resources Agency or the Governor's Office, using cap-and-trade revenue, state bond or federal funding to establish it.
- The office should include an Agriculture Division that prioritizes coordination with the California Air Resources Board and California Department of Food and Agriculture to provide research, technical assistance and cost sharing for farmers and ranchers to adopt practices that reduce agriculture's vulnerabilities to a changing climate.
- Given California's vulnerability to water scarcity, which will only increase as climate change impacts are realized, particular attention should be paid to expanding the use and diversity of water-conserving agricultural practices.

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## Appendix A: Summary of State and Federal Adaption and Mitigation Studies Included in Report

### Key:

Organic indicator: Here, we noted if the research project included a “focus” on organic agriculture (e.g. research was conducted on an organic farm exclusively), if organic agriculture was a “component” of the study (e.g. in comparison with conventional systems) or “no” was not included in the study. All other indicators: “Yes” is used to indicated that this approach was included in the research project; “No” is used if the approach was not included.

### State Adaptation and Mitigation Studies

Project Title	Funding Agency	Organic	Water and Energy	Integrated	Reduced Inputs	Economics	Social
Assessing Impacts of Rangeland Management and Reforestation of Rangelands on Greenhouse Gas Emissions: A Pilot Study for Shasta County	CEC (PIER)	No	No	Yes	No	No	No
Assessment of Greenhouse Gas Mitigation in California Agricultural Soils	CEC (PIER)	Component	No	Yes	Yes	Yes	No
Carbon Sequestration and GHG Emissions in Intentionally Flooded Corn Fields in the Delta	CEC	No	No	No	No	No	No
CATNIP Strategy 3: Research on GHG Emissions from Nitrogen Fertilizer	CDFA, ARB, CEC	Component	Yes	Yes	Yes	No	No
Climate Change Impacts on Water Supply and Agricultural Water Management in California’s Western San Joaquin Valley, and Potential Adaptation Strategies—Final Report	CEC (PIER)	No	Yes	No	No	No	No
Ecological Footprint of Walnuts	CDFA (specialty crop)	Component	No	Yes	Yes	Yes	No
Heat-tolerant Lettuce and Spinach Varieties for Adaptation to Global Warming and Low Land Cost Areas of California	CDFA (specialty crop)	No	No	No	No	Yes	No
Potential for Adaptation to Climate Change in an Agricultural Landscape in the Central Valley of California—Final Report	CEC (PIER)	Component	Yes	Yes	Yes	Yes	Yes
Reducing Our Footprint: Minimizing Greenhouse Gas Emissions and Nitrogen Leaching in Vineyards, and Enhancing Landscape Carbon Stocks	CDFA (specialty crop)	No	No	Yes	Yes	No	No
The Potential of Biochar Soil Amendments as a Carbon Sequestration Method in California Agriculture	CEC	Component	No	No	No	No	No
Scaling Soil Biogeochemical Processes in an Annual Grassland Ecosystem: The Interactive Effects of Management and Climate Change	UCD Kearney Foundation	No	No	Yes	No	No	No
Controls on Greenhouse Gas Emissions in Managed Soils	UCD Kearney Foundation	No	No	Yes	No	No	No

## Federal Adaptation and Mitigation Studies

Project Title	Funding Agency	Organic	Water and Energy	Integrated	Reduced Inputs	Economics	Social
Agricultural Sustainability and the Central Valley: An Economic Analysis of the Impacts from Changes in California's Water Supply	NIFA CALB	No	No	Yes	No	Yes	No
Applications of Systems Analysis to Problems in Agriculture and Resource Management	NIFA CALB	No	Yes	No	No	No	No
California Integrated Network to Enhance Sustainable Agroecosystem Science	NIFA CALB	No	No	No	Yes	Yes	Yes
Creating and Quantifying Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment	NRCS CIG	No	No	No	Yes	No	No
Development of Protocols and Accounting Methods for Carbon Sequestration on US Rangelands	NRCS CIG	No	No	No	Yes	No	No
Effect of Plant Growth Zones on Soil Quality in the Rhizosphere	NIFA CALB	No	No	No	No	No	No
Greenhouse Gas Emissions and Mitigation in Agriculture	NIFA CALB	Component	Yes	No	Yes	No	No
Integration of Ruminant Digestive, Metabolic and Energetic Relationships	NIFA CALB	No	Yes	No	No	No	No
Irrigation Alternatives for Sustainable Water Use of Processing Tomatoes	NIFA - SARE	No	No	Yes	Yes	Yes	No
Irrigation Energy and Water Use Efficiency Evaluation and Demonstration Using Telemetry Equipment for Remote Monitoring and Evaluation for Irrigation and Integrated Pest Management Planning and Timing	NRCS CIG CA	Focus	No	Yes	No	No	No
Microirrigation for Sustainable Water Use	NIFA CALB	No	No	Yes	No	No	No
Modeling Agricultural Production and Resource Use	NIFA CALB	No	No	No	No	Yes	No
Multi-Campus Applied Agriculture and Environmental Research Projects Administered by CSU, Fresno	NIFA CALW	Component	No	No	Yes	Yes	No
Nutrient Dynamics, Soil Biota and Functional Biodiversity at an Organic Farm	NIFA CALB	Focus	No	Yes	Yes	Yes	Yes
Prescribed Grazing to Sustain Livestock Production, Soil Quality, and Diversity in Rangeland Ecosystems	NIFA - SARE	No	No	No	Yes	Yes	Yes

Rapid Soil Nitrate Sensor	NSF- IPP	No	Yes	No	No	Yes	No
Regional Analysis of Biological Control and Biotechnology in Sustainable Agricultural Systems	NIFA CALB	No	No	No	No	No	no
Reproductive Biology of Tree Fruit and Nut Species: Olive Cultivar Compatibility Relationships	NIFA CALB	No	No	No	No	No	No
Researcher and Farmer Innovation to Increase Nutrient Cycling on Organic Farms	NIFA CALB	Focus	No	Yes	Yes	Yes	Yes
Smart-rate Technology: Improving fertilizer use efficiency	NRCS CIG	No	Yes	No	No	No	No
Soil Biology in Vegetable Crop Systems	NIFA CALB	Component	No	No	Yes	No	No
Spatial Distribution of Soil Biota, Mycorrhizae, Roots and Soil Nitrogen Transformations	NIFA CALB	Focus	No	No	Yes	No	No
Stress Physiology of Vitis Rootstocks and Greenhouse Gas Production and Consumption by California Perennial Crops	NIFA CALB	No	Yes	Yes	Yes	No	No
Sustainability Economics of Agricultural Production in Resource-Constrained Environment	NIFA CALB	No	Yes	Yes	No	Yes	No
Understanding the Impact of the Trans-Acting Sirna Pathway on Male Fertility in Rice	NIFA CALB	No	No	No	No	No	No
Water Management for Sustainable Agricultural Development	NIFA CALB	No	No	Yes	No	No	No
Water Policy and Management Challenges in the West	NIFA CALB	No	No	Yes	No	Yes	No



## Appendix B: Summary of State and Federal Climate and Agriculture Studies Not Included in Report

As described in Section Three, these studies were not included in our review. We note the funding source where available (e.g. CDFA's Speciality Crop Block Grant program or CEC's PIER program).

Study types include:

- Impacts (e.g. climate change impacts on agriculture, agriculture's contribution to GHG emissions)
- Renewable Energy (e.g. development of bioenergy projects)
- Policy Analysis (e.g. reviewing climate change policy implications for agriculture)
- Biofuels (e.g. development of transportation fuels from agricultural feedstocks)
- Planning Grant

### State-Funded Studies

Project Title	Funding Agency(s)	Project Lead Institution	Study Type
California Perennial Crops in a Changing Climate	CEC (PIER)	Stanford	Impacts
Can Photo-degradation Elucidate Spatial and Temporal Variation in CO <sub>2</sub> Fluxes in a California Grassland Ecosystem?	UC Kearney Foundation	UC Davis	Impacts
Climate Extremes in California Agriculture	CEC (PIER)	Stanford	Impacts
Compositional Fractionation Resulting from DOC Sorption to Soil Minerals: Implications for Soil Organic Matter Stabilization and Sequestration	UC Kearney Foundation	UC Davis	Impacts
Dairy Methane Digester System Program Evaluation Report	CEC (PIER)	Western United Research Development	Renewable Energy
Dairy Waste to Energy	CEC	CEC: Biomass—Anaerobic Digestion Projects	Renewable Energy
Developing and Applying Process-Based Model for Estimating Greenhouse Gas and Air Emissions From California Dairies	CEC (PIER)	Applied Geosolutions, LLC & Complex Systems Research Center, University of New Hampshire	Impacts
Do Soil Microbial Community Characteristics Impact Spatial and Temporal Patterns of Humification?	UC Kearney Foundation	UC Berkeley	Impacts
Economic Impacts of Climate Change on California Agriculture	CEC (PIER)	UC Santa Barbara	Impacts
Effect of Climate Change on Field Crop Production in the Central Valley of California	CEC (PIER)	UC Davis	Impacts
Energy Crops Research	CDFA/CEC	CDFA/CEC	Biofuels
Enhanced Energy Recovery through Optimization of Anaerobic Digestion and Microturbines Project	CEC	CEC: Biomass—Anaerobic Digestion Projects	Renewable Energy
Estimating the Economic Impacts of Agricultural Yield-Related Changes for California	CEC (PIER)	UC Davis	Impacts
Exploration for Soil Biodiversity at the Landscape Scale	UC Kearney Foundation	UC Davis	Impacts
Farm-Based Clean Energy Technologies	CDFA	CDFA	Renewable Energy
Fog/Wind Chill in Central Valley	CEC	UC Berkeley	Impacts

Link Rhizosphere Priming to Temperature Sensitivity of Soil Organic Carbon Decomposition	UC Kearney Foundation	UC Santa Cruz	Impacts
Litter Photodegradation Impacts On Dissolved Organic Matter Formation And Persistence In California Grassland Soils	UC Kearney Foundation	UC Santa Cruz	Impacts
National Air Emissions Monitoring (NAEMS) Project: Air Emissions from California Dairies	ARB, CDFA	UC Davis	Impacts
Spatial and Temporal Dynamics of Biogenic Silica in Californian Grassland Soils	UC Kearney Foundation	UC Berkeley	Impacts
Root Herbivores in an Orchard System: Assessing the Influence of Root Herbivory and Pest Management on Root Dynamics, Soil Fauna, and Soil Carbon Pools	UC Kearney Foundation	UC Davis	Impacts
Spatial and Temporal Dynamics of Deep Soil Gaseous and Soluble Element Fluxes from New vs. Old Organic Matter	UC Kearney Foundation	UC Davis	Impacts
Temporal and Spatial Patterns of Soil Organic Matter Losses in California Determined by Radiocarbon Dating of Riverborne Carbon	UC Kearney Foundation	UC Riverside	Impacts
The Combined Drought Strategies of Soil Microbial Communities Shape Wet-up CO <sub>2</sub> Pulses in Mediterranean Annual Grasslands	UC Kearney Foundation	UC Berkeley	Impacts
The Effects of Agriculture and Snow Impurities on Climate and Air Pollution in California	CEC (PIER)	Stanford	Impacts
The Production and Isotope Composition of Soil N <sub>2</sub> O Along Gradients of Climate and Time	UC Kearney Foundation	UC Berkeley	Impacts
The Role of Microbial Community Function in Spatial and Temporal Variation of Nitrous Oxide Gas Emissions from California Perennial Cropping Systems	UC Kearney Foundation	UC Davis	Impacts
Tree Phenology Models for Climate Change Projection and Improved Water and Nutrient Management	CDFA (Specialty Crop Block Grant)	UC Davis	Impacts
Understanding Variability in Soil N and C Dynamics Over Space and Time—The Role of Plant Population Dynamics	UC Kearney Foundation	UC Davis	Impacts

### Federally Funded Studies

Project Title	Funding Agency(s)	Project Lead Institution	Study Type
Agronomic Practices Affecting Yield, Forage Quality and Sustainability of Irrigated Forage and Biofuel Crops	NIFA CALB	UC Davis	Biofuels
Analysis of Eco-Social and Climate Change Effects on California Agricultural Systems: An Integrated Physiologically based Geospatial Modeling Approach	NIFA CALB	UC Berkeley	Impacts
Assessment and Mitigation of Whole Farm Sustainability and Emission from Dairy Production Systems in the Arid West	NIFA CALB	UC Davis	Planning Grant
Assessment of Potential Impacts of Climate Change and Variability in the California Region: Phase II	NSF - AGS	UC Santa Barbara	Impacts

Bacterial Enzymes and Activities of Agricultural and Biofuels Interests	NIFA CALB	UC Davis	Biofuels
Benchmark Soils to Predict Effects of Climatic Change in the Western USA	NIFA CALB	UC Davis	Impacts
Benchmark Soils to Predict Effects of Climatic Change in the Western USA	NIFA CALB	UC Riverside	Impacts
Benefits and Costs of Natural Resources Policies Affecting Public and Private Lands	NIFA CALB	UC Berkeley	Impacts
Biogeochemical Functioning of Soils and Sediments: A Multiscale Integration of Microbial Ecology, Environmental Physics and Geochemistry	NIFA CALB	UC Berkeley	Impacts
California State University Agricultural Research Initiative-FFI 2008	NIFA CALR	Cal State Fresno	Biofuels
Carbon and Nitrogen Interchange in the Rhizosphere: Sensitivity to Temperature and Water Dynamics	NIFA CALR	UC Santa Cruz	Impacts
Cascading Effects of Climate Change on an Invasive Insect Vector and Disease Spread in Vineyards	NIFA CALB	UC Riverside	Impacts
Characterization of Sources and Processes of Primary and Secondary Particulate Matter (PM) and Precursor Gases in the California-Mexico Border Region	NSF - AGS	Molina Center for Strategic Studies in Energy & the Environment	Impacts
Climate Change and Air Pollution: Second Order Ozone Impacts, Mitigation of Fugitive Dust and Novel Biofuels to Reduce Greenhouse Gases	NIFA CALB	UC Riverside	Biofuels
Climate Change and Natural Resource Management in California	NIFA CALB	UC Davis	Impacts
Climate Change Effects in California: Fire Regimes, Vegetation Boundaries, and Perennial Crops	NIFA CALB	UC Davis	Impacts
Collaborative Research: Characterization of Sources and Processes of Primary and Secondary Particulate Matter (PM) and Precursor Gases in the California-Mexico Border Region	NSF - AGS	UC San Diego - Scripps	Impacts
Cost of Greenhouse Gas Regulation	NIFA CALB	UC Berkeley	Policy Analysis
Distinguishing between Greenhouse Gas Emissions from Cropland, Animal Operations, and Urban Land Cover Isotopic Tracers	NIFA CALR	UC Irvine	Impacts
Ecosystem Carbon-Water Interactions in a Changing Climate	NIFA CALB	UC Berkeley	Impacts
Engineering Switchgrass to Express Cell Wall-Degrading Enzymes	ARS 5325	Western Regional Res Center	Biofuels
Environmental Controls over Methyl Halide Emissions from Agricultural Rice Paddy Ecosystems"	NSF - DEB	UC Irvine	Impacts
ETBC—The Cycling of Nitrogen in an Earth System Model: Constraints and Implications for Climate Change	NSF - AGS	UC Irvine	Impacts
Exotic Pests and Diseases (CA)	NIFA CALB	Independent, UC	Impacts
How Will Altered Rainfall Patterns Predicted for Northern California Impact Soil Microbial Diversity and Solute Fluxes to Watersheds?	NIFA CALB	UC Berkeley	Impacts

Improving the Sustainability of Livestock and Poultry Production in the United States	NIFA CALB	UC Davis	Renewable Energy
Increasing opportunities for renewable energy production from methane digesters	NRCS CIG CA	Sustainable Conservation	Renewable Energy
Introducing 80% Efficient Micro-CHP Technology to California Viticulture	NRCS CIG	Putah Creek Winery, Propane Education & Research Council	Renewable Energy
Microbial Control of Nitrogen Oxide Production in N-Impacted Environments	NIFA CALB	UC Riverside	Impacts
Modeling California Water Economics and Policy	NIFA CALB	UC Davis	Impacts
Modeling the Chemistry of the Nitrite and Sulfite Reductases	NSF - CHE	UC Irvine	Impacts
Modular Biopower for Conservation of Winery Biomass Residues to On-site Heat and Power	NRCS CIG	Pine Ridge Winery	Renewable Energy
Natural Resource Management, Environmental Regulation and Policy	NIFA CALB	UC Davis	Policy Analysis
Networks of Sustainable Agriculture and Food in California's Central Valley	NIFA CALB	UC Davis	Impacts
Overcoming Limitations in Solid State Bioconversion of Lignocellulosic Biomass to Biofuels and Other Bioproducts	NIFA CALB	UC Davis	Biofuels
Perceptions of and Responses to Climate Variability and Change in Agriculture, Fisheries and Natural Resource Management	NIFA CALB	UC Davis	Policy Analysis
Plant Cell Wall Polysaccharides—Biosynthesis, Structure, Function, and Application as a Renewable Resource	NIFA CALB	UC Berkeley	Biofuels
Plant Community Dynamics on Rangeland Ecosystems	NIFA CALB	UC Berkeley	Impacts
Production and Mitigation of Volatile Organic Gases From Dairies	NIFA CALB	UC Davis	Impacts
Reactivity, Aggregation and Transport of Nanocrystalline Sesquioxides in the Soil System	NIFA CALR	UC Berkeley	Impacts
Regional Analysis of Biological Control and Biotechnology in Sustainable Agricultural Systems	NIFA CALB	UC Berkeley	Impacts
Reproductive Biology of Tree Fruit and Nut Species: Olive Cultivar Compatibility Relationships	NIFA CALB	UC Davis	Impacts
Science, Technology & Environment in California	NIFA CALB	UC Berkeley	Policy Analysis
The Biofuels Acceleration Project (BAP)—Using Voluntary Markets for the sale of Biofuel-Sourced Projects "Credits" to Accelerate the Production of "High-Benefit" Liquid Biofuels	NRCS CIG	AP-Garm SC, LLC AgRefresh	Biofuels
The Science and Engineering for a Biobased Industry and Economy	NIFA CALB	UC Davis	Biofuels

## **The California Climate & Agriculture Network**

The California Climate and Agriculture Network (CalCAN) is a collaboration of California's leading sustainable agriculture organizations and allies advocating for policy solutions at the nexus of climate change and agriculture. We have come together as a coalition to cultivate farmer leadership to face the challenges of climate change and to serve as the sustainable agriculture voice on climate change policy in California.



## **California Climate & Agriculture Network**

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