AGRICULTURE

Agricultural Land Conservation

Ecosystem Service Benefits

- The public demonstrates a preference for preventing farms and ranches from development and may be willing to pay between $140,000 and $35 million per year for the acres conserved.
- Another way to measure how the public values the conservation of farmland is through increases in property values of nearby parcels. CCI projects may increase market prices for up to 17,000 parcels between $5,900 to $1.6 million on an annualized basis.
- The agricultural production sustained through these projects also generates revenue for farmers. Crops produced on this land may have a market value of $110 million per year. This revenue contributes to maintaining agriculture as a viable livelihood for farmers.
- Continued local agricultural production may also contribute to regional food security.

OVERVIEW OF PROJECTS

Project activities
Conserve productive farmland and ranchland under threat of development

Implementing agency
California Department of Conservation

34 projects
funded across 19 counties (2015-2019)

43,000 acres
of cropland and ranchland conserved

Between 2015 and 2019, CCI invested in 34 projects through the Sustainable Agricultural Lands Conservation (SALC) Program at the California Department of Conservation. The primary activity for these projects is conserving productive farmland and ranchland under threat of development in perpetuity. During this five-year period, CCI conserved 43,000 acres across 19 counties, about 8 percent of which is cropland and 92 percent ranchland (CARB 2021).[14] The two counties with the most conserved acres are Butte and Napa, although the most projects are found in Monterey. Relative to the agricultural land conserved pre-CCI (GreenInfo Network 2022), these projects are increasing land devoted to agricultural easements by 0.03 percent in Lassen County to 10 percent in Napa County.

This analysis documents the societal benefits related to keeping agricultural land in productive use. Appendix page A-2 describes the pathways through which these projects generate environmental changes as well as ecosystem service benefits. Relative to developed land, agricultural land provides pollinator and wildlife habitat, acts as a catchment for stormwater, provides green and open space that can reduce the likelihood of heat island effects, provides food sources for people, and sustains income and a livelihood for farmers. To demonstrate how people value these services, the analysis includes information on two different measures: 1) an overall WTP reflecting people's preference for maintaining agricultural land and 2) an assessment of the property value benefits to nearby parcels. In addition to these measures of broad societal values, the analysis also considers the commercial revenues to farmers associated with keeping agricultural land in productive use. Finally, the benefits to regional food supplies and habitat for species are qualitatively summarized.

Willingness to pay (WTP) to conserve farmland.[15]
There are several possible ecosystem service benefits of conserving farmland in rural areas, including aesthetic values and the values people place on the habitat sustained by agricultural land (McConnell and Walls 2005). Beyond benefits associated with the environmental attributes of farmland, people may also value the continued existence of the agricultural way of life, source of local food, among other broader socioeconomic benefits. While no studies are specific to residents of California, evidence from across the United States consistently demonstrates that people are willing to pay to prevent the conversion of agricultural land to developed land. A literature search identified six studies that offer information on WTP per acre of farmland conserved per household per year (Bergstrom et al. 1985; Beasley et al. 1998; Rosenberger and Walsh 1997; Johnston et al. 2001; Swartzentrauber 2019; Johnston and Duke 2007).[16] After dropping two high-end outliers, these studies provide a range of $0.046 to $12 per 1,000 acres conserved per household per year.[17] Applying these values to the nearly 43,000 acres conserved across CCI projects and the 1.8 million households in the counties in which the farms and ranches are found (according to U.S. Census data), the analysis suggests

[14] There were about 450 acres that were not valued, primarily due to being open water, developed land (together about 1.313 percent of total acreage), or, to a significantly lesser extent, a crop with no value in the data (0.048 percent of total acreage).

[15] From an economic perspective, WTP is a conceptually appropriate measure of value of a resource or service. WTP is the maximum amount of money an individual would voluntarily exchange to obtain a resource or environmental improvement, given budget constraints. In other words, WTP indicates the point at which the individual would be equally satisfied with having the good itself or with having the money to spend on other things.

[16] Four of these studies were summarized in McConnell and Walls (2005). This analysis added two studies published since 2005 to establish the range.

[17] The two outliers included WTP for coastal farmland in New York (Johnston et al. 2001) and farmland in Alaska (Beasley et al. (1998), which are both sufficiently different from the cropland and ranchland conserved by CCI.

that Californians may value the agricultural acres conserved by CCI between **$140,000 and $35 million per year**.[18] This broad range reflects the uncertainty associated with this outcome at a given project site.

Increased property values for nearby residents.
Another way to measure the value of conserving farmland is through increases in property values of adjacent parcels. To demonstrate the potential effects of CCI projects on property values, this analysis considers findings from Geoghegan et al. (2003), which studies increases in property values associated with increases in agricultural land conserved across two counties experiencing development pressure in Maryland. The study authors find that homes within 100 meters (m) of an agricultural easement experience a 0.04 percent increase in market value in one county while homes within 1,600 m experience a 0.71 percent increase in a different county. We use the property value benefit experienced by households within 100 m of the projects as a low-end estimate for the overall property value effect of the projects and the benefit experienced by households within 1600 m as the high-end. Spatial analysis identifies over 550 parcels within 100 m and over 17,000 within 1,600 m of the CCI projects (County of Los Angeles 2022). Assuming all identified parcels are valued at the median home price for the county (U.S. Census Bureau 2020), this analysis suggests the property value benefits of the conserved acres may be between $190,000 and $51 million in present value terms, equivalent to **$5,900 to $1.6 million on an annualized basis** (assuming a 3 percent discount rate).

Commercial revenues from sustained agricultural production.
In addition to the benefits experienced by the public and nearby property owners, sustaining agricultural production ensures continued commercial revenue to farmers. This analysis first used spatial data from the U.D. Department of Agriculture (USDA 2021a) to identify the primary crop or fodder agricultural product on each conserved parcel outlined in geospatial data provided by SALC (2022). Across all conserved acres, 69.0 percent (approximately 29,000 acres) are classified as shrubland or grassland/pasture, while forests and wetlands make up about 23.4 percent (approximately 9,900 acres). Among parcels with crop production (7.6 percent of acres, equivalent to 3,200 acres), the primary crops include alfalfa, olives, and rice. Then, to determine the magnitude of potential revenue from selling the crops and fodder from these fields, data from the California Agricultural Statistics Review and the USDA Land Values Summary were incorporated to assign an average market value, in dollars per acre, for each crop or land use type. Overall, these acres can produce crops and fodder valued at **$110 million annually**, equivalent to about $2,700 per acre. For reference, the total farm receipts in California for 2020-2021 was $49 billion across 24 million acres (CDFA 2021).[19]

[18] Both of the underlying studies represented in the range also extrapolated their findings to households within the county.

[19] Not included in this assessment is the value of livestock and other animals sustained by the agricultural land conserved, which may be significant given the high proportion of ranchland.

Beyond revenue, agriculture also represents a livelihood and way of life for many Californians. According to the California Department of Food and Agriculture's Agricultural Statistics Review, California's agriculture industry "supports 1.2 million jobs, including the vital farmworkers who labor to harvest, process, and transport California's agricultural bounty" (CDFA 2021). Though California is responsible for nearly 14 percent of agricultural production in the United States, most farming operations in California are small (CDFA 2021). In 2020, 71 percent of farms brought in less than $100,000 in sales, whereas only 14 percent brought in more than $500,000 (CDFA 2021). Many of the farmers running these small-scale operations work the land they live on. For these individuals, the conservation of farmland is necessary to protect both their homes and incomes.

Improved regional food security.
Agricultural land easements also have the potential to support California's regional food security. By conserving local, arable land, agricultural easements protect California from out-of-state and international agricultural supply shocks. Protecting a parcel by restricting nonagricultural development "gives a relative priority to economic and food security objectives. It may be the most effective, pragmatic, and tailored approach for a given project, land trust, geographic area, or even type of working landscape" (Phelps 2017). In addition to the other benefits characterized above, we anticipate that the conservation of nearly 43,000 acres of cropland and ranchland will further bolster California's regional food security.

Positive preference for protection of species habitat.
Many of the agricultural easements provide habitat for species or a buffer between developed sites and important ecosystems, like rivers, grassland, and woodland. Depending on location, some of the conserved properties may function as habitat during annual migrations or for breeding specifically. The economics literature generally finds that people have a positive preference for increasing the conservation of species of concern, including endangered and threatened species. However, data are not available to quantify or monetize these benefits.

Table 3: Summary of Monetized Ecosystem Service Benefits for the Agricultural Land Conservation Projects by County (2021 dollars)

County	Total Acres Conserved[a]	WTP for Conserved Agricultural Land (Annual)[b,c]	Increased Property Values (Annualized)[b,c]	Commercial Value of Agricultural Production (Annual)[b]
Butte	9,100	$35,000 - $8,900,000	$1,000 - $56,000	$28,000,000
Calaveras	3,300	$2,500 - $640,000	$1,600 - $310,000	$9,100,000
Contra Costa	520	$9,600 - $2,400,000	<$100 - $100,000	$640,000
Humboldt	2,900	$7,300 - $1,900,000	<$100 - $8,300	$4,100,000
Lassen	580	$250 - $62,000	<$100 - $1,300	$510,000
Marin	330	$1,600 - $400,000	<$100 - $4,700	$790,000
Mariposa	280	$100 - $26,000	--	$830,000
Merced	60	$230 - $57,000	<$100 - $520	$280,000
Mono	2,400	$570 - $140,000	<$100 - $820	$4,700,000
Monterey	1,900	$11,000 - $2,800,000	$190 - $220,000	$6,400,000
Napa	13,000	$29,000 - $7,200,000	$1,600 - $110,000	$36,000,000
Placer	860	$5,800 - $1,500,000	<$100 - $18,000	$2,200,000
San Joaquin	120	$1,300 - $330,000	<$100 - $4,500	$220,000
San Luis Obispo	1,800	$8,700 - $2,200,000	<$100 - $2,200	$4,100,000
Santa Cruz	49	$220 - $55,000	<$100 - $31,000	$310,000
Shasta	670	$2,200 - $550,000	<$100 - $390	$1,500,000
Sierra	690	<$100 - $10,000	<$100 - $4,500	$1,600,000
Solano	2,200	$15,000 - $3,900,000	$780 - $340,000	$6,100,000
Yolo	2,400	$8,400 - $2,100,000	$380 - $390,000	$7,700,000
Statewide Total	**43,000**	**$140,000 - $35,000,000**	**$5,900 - $1,600,000**	**$110,000,000**

Sources and notes:

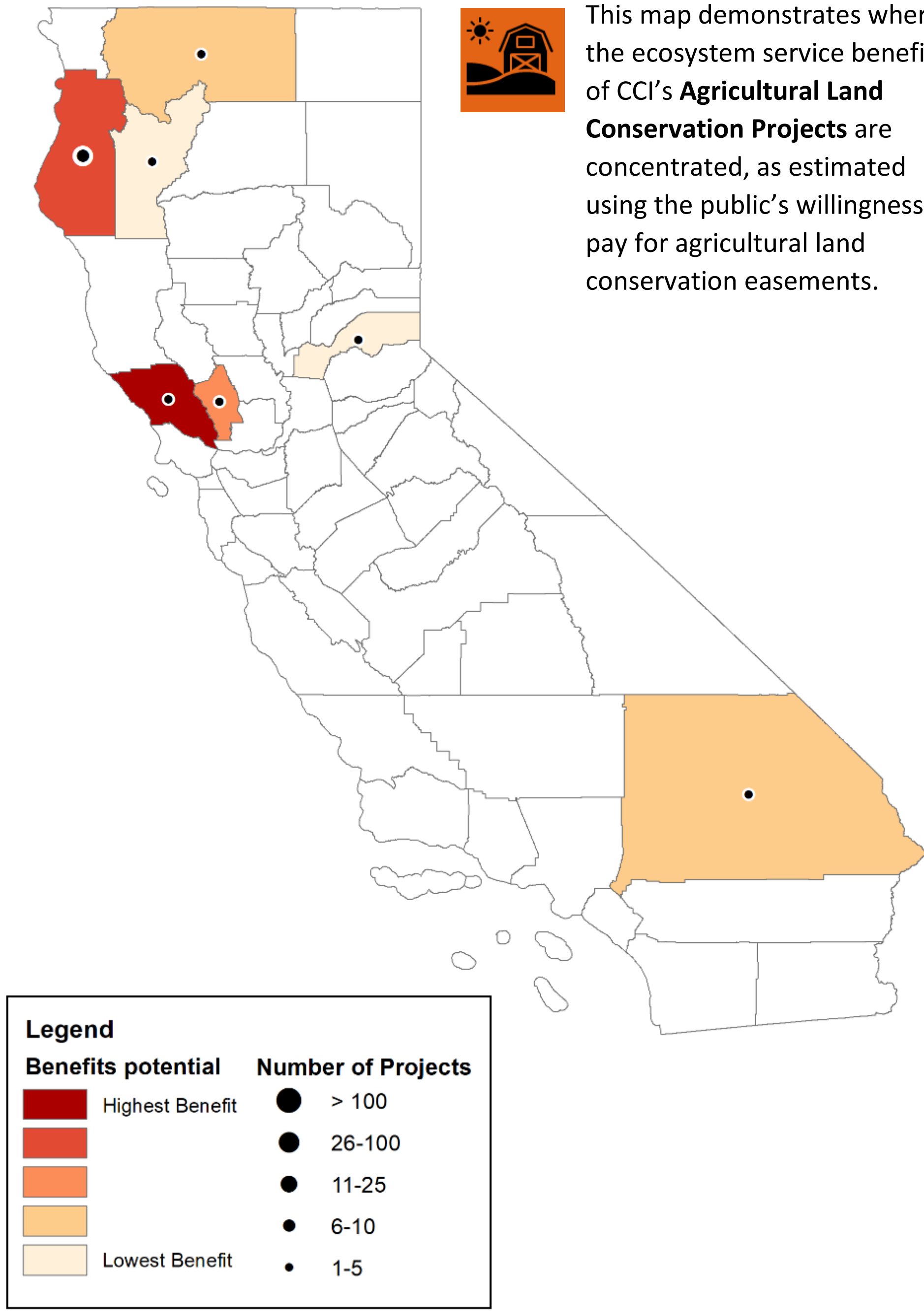
a. Data observed in CARB (2021) considering projects implemented from 2015 to 2019.

b. Author calculations described in this report. The monetary values presented in this table are not necessarily additive to a single, total benefits value as they reflect alternative valuation methods and measures (e.g., market values, social welfare values) and may double-count the same benefit stream.

c. When "<$100" is used to express the low-end of a range, the expected value of the metric is between a value less than $100 and the high-end value.

Figure 3: Spatial Distribution of Ecosystem Service Benefits Potential for the Agricultural Land Conservation Projects

This map demonstrates where the ecosystem service benefits of CCI's **Agricultural Land Conservation Projects** are concentrated, as estimated using the public's willingness to pay for agricultural land conservation easements.



Note: The benefit potential conveyed in this map reflects the WTP for conserved agricultural land (as opposed to solely the acreage of land conserved), as presented in Table 3. The high-end value of the range is included.

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AGRICULTURE

On-farm Conservation Management

Ecosystem Service Benefits

- On-farm conservation management practices lead to increases in soil organic matter (SOM), resulting in more nutrient-rich and biologically active soils. This makes soils more resistant to erosion and more effective in water filtration, which reduces drinking water maintenance needs, increases retention of plant-available water, and improves fish habitat. The annual benefits that may accrue from improved soil health range from $2,500 to $10 million.
- These practices can also create pollinator habitat, potentially increasing yields of pollinator-dependent crops at an average value of $2 million per year.
- Improvements in regional food security and habitat for non-aquatic species are also possible through these practices.

OVERVIEW OF PROJECTS

Project activities
Implement farming practices that improve soil health and the environmental conditions of agriculture

Implementing agencies
California Department of Food and Agriculture; State Coastal Conservancy

482 projects
funded across 46 counties (2018-2020)

37,000 acres
with improved soil practices

5,700 acres
of new pollinator habitat

The California Department of Food and Agriculture (CDFA) and State Coastal Conservancy (SCC) implemented 482 projects aiming to improve soil health from 2018 to 2020. Project activities include on-farm conservation management practices such as cover cropping, no or reduced till farming, mulching, compost application, and conservation plantings. Through the implementation of these practices, 37,000 acres of soil were improved, and 5,700 acres of new pollinator habitat established (CARB 2021). Projects spanned 46 counties, with the greatest soil benefits achieved in Sutter and Yuba counties and the largest amount of new pollinator habitat established in Yolo and Tulare counties.

Appendix page A-3 describes the pathways through which these projects generate environmental changes as well as ecosystem service benefits. Increased soil organic matter (SOM) is a primary benefit of implementing on-farm conservation management practices. SOM is the portion of the soil comprised of plant or animal matter and is a useful proxy for the health and productivity of soils (Cornell University Cooperative Extension 2008). This analysis measures benefits flowing from increased SOM including increased availability of nutrients, greater water retention, and reduced soil erosion, which in turns leads to ecosystem service benefits such as increased agricultural production, reduced need for water supply maintenance, and avoided water treatment costs. For the purposes of this analysis, information about changes in SOM from demonstration plots funded by CDFA are used as a proxy for changes in SOM across all projects in this category. We assume these short-term increases in SOM will persist over time as conservation management practices become more routine. This analysis also values benefits from increased pollinator habitat from practices like adding hedge rows and planting cover crops. These benefits include increased agricultural yields and improved habitat.

CCI projects increase soil organic matter.

Of the 482 projects, 11 projects function as demonstration plots used for research and as teaching tools for farmers and ranchers. These projects contribute to a better understanding of how the practices encouraged and funded by CCI contribute to improvements in soil health over time. Data on measured SOM on demonstration plots were available for these 11 demonstration projects, many of which studied multiple practices across multiple plots (CDFA 2021). Comparing changes in SOM from pre-project levels and relative to "control" plots that maintained pre-project practices on the same farms, the data show average increases in SOM of **0.15 percent after one year, 0.20 percent after two years, and 0.60 percent after three years**.[20,21] While variations across practices and project sites can be substantial, data are insufficient to calculate changes in SOM by project. Instead, we apply the average observed increases in SOM described above for these 11 projects to all 37,000 acres identified to assess the potential ecosystem service benefits associated with these improvements. Importantly, these demonstration plots only tracked changes for up to three years, and these plots are expected to continue to accrue SOM benefits over time.

[20] The types of management practices covered by these data include but are not limited to composting, applying wood chips, planting cover crops (both legumes and non-legumes), mulching, and combinations that considered multiple of these practices simultaneously (e.g., compost and cover crops). While the practices supported by CCI fall into specific classifications defined by USDA's Natural Resources Conservation Service (NRCS), we refer to them using more general terms in this report.

[21] To derive these numbers, we calculated the difference between SOM measured on the treatment plots (T) and control plots (C) at each time period (t) then divided that difference by the difference between the treatment and control plots before project implementation (t=0). For example, after one year of project implementation (t=1), the change in SOM is: $(T_1-C_1)/(T_0-C_0)$. The change in SOM was calculated for each demonstration plot then averaged across all plots with data points in each of the three years. These measures represent percent by weight per year and are a standard way of conveying the amount of organic matter in soils.

Commercial value of additional nutrients in improved soils. As SOM decomposes, nutrients are released and made available to plants. In some cases, these nutrients displace the need for additional fertilizer. In other cases, they supplement the nutrients farmers apply to their fields. A standard rule of thumb for temperate regions is that, at an average mineralization rate of 1.5 percent, each percent of organic matter contains up to 17 pounds of nitrogen and 1.75 pounds of phosphorus (NRCS 2023). These two nutrients are essential for sustained agricultural production; nitrogen is responsible for crop yields while phosphorous is required for plant maintenance. Given the SOM trajectories observed on the CCI demonstration plots described above, this translates to 10.2 pounds of nitrogen per acre and 1.05 pounds of phosphorus per acre after implementing the healthy soils practices for three years. In total, this translates to **over 370,000 pounds of additional plant-available nitrogen and nearly 39,000 pounds of phosphorus** across the 37,000 project acres implementing healthy soils practices.

To value these added soil nutrients, we use the commercial cost of nitrogen and phosphorus-based fertilizers paid by farmers from studies providing sample costs to produce various crops (UC Davis 2018-2021). On average, the analysis finds these nutrients costs California farmers about $5.30 per pound of nitrogen and $6.80 per pound of phosphorus.[22] Combined with the total area under these improved soil conditions, this analysis calculates the potential value of additional nutrients in soil to be about **$2.2 million** per year. Eighty-eight percent of the total average value is attributed to increases in soil nitrogen, and 12 percent is attributed to increased phosphorus in the soil. Increasing SOM levels also may increase the presence of other soil nutrients besides nitrogen and phosphorous, therefore this value likely represents an under-estimate of the total potential magnitude of additional soil nutrients benefits of these practices.[23]

Avoided water treatment and water use costs from reduced soil erosion. Increases in SOM are linked to decreased soil erosion, which leads to a reduction in the amount of sediment that could enter into waterways serving as drinking water sources. To the extent that these projects are located in areas that also serve as drinking water sources, people benefit from soil stabilization through reduced drinking water treatment costs. The universal soil loss equation (RUSLE) is used to predict soil losses given site-specific soil properties, management practices, and other influential environmental conditions like rainfall (Tisdale et al. 1985). The equation considers cropping and management conditions, although soil organic matter improvements do not enter directly into the model. Data used in the universal soil loss equation indicate that increasing SOM from 1 to 3 percent can reduce erosion 20 to 33 percent due to increased water infiltration and stable soil formation (Funderburg 2001). Using the increases in SOM found in the project demonstration plots, we scale the percent decrease in soil erosion by the mean increases in SOM observed in the plots, resulting in a 6 to 9.9 percent reduction in erosion. The soil loss in the Pacific region is estimated to be 1.8 tons per acre

[22] To calculate these costs per nutrient, we decomposed the total cost of the fertilizer into the component nutrients. For example, NPK 15-5-5 contains 15 percent nitrogen and 5 percent phosphorus. We then apply these percentages to the total cost of the fertilizer per pound to create an equivalent cost per pound of nitrogen and phosphorous. The reports reviewed for this report included 15 fertilizer types used on several crops (alfalfa, almond, avocado, blackberries, pistachios, etc.).

[23] These other essential nutrients include but are not limited to calcium, magnesium, and potassium (Cornell University Cooperative Extension 2008).

each year (NRCS 2007). Adjusting this baseline soil loss by a low end and high-end estimate of SOM increases from the demonstration plot data, we estimate a **total reduction in soil loss between 4,000 and 6,500 tons per year** across the 37,000 acres where on-farm conservation management practices were implemented.

Decreased soil erosion can benefit people in various ways. The USDA's Economic Research Service (ERS) developed a methodology to monetize the economic benefit of soil conservation benefits specifically associated with decreased soil erosion (Hansen and Ribaudo 2008a). Among other things, the methodology considers water quality improvements and subsequent impacts on industries, municipalities, and households.[24] Across California, the data reveals that the avoided municipal and industrial water treatment and water use to be $0.64 per ton of soil retained. Applying this valuation to the above estimated reduction in soil loss, this analysis suggests welfare gains associated with avoided water treatment and water use costs of these projects may be between **$2,500 and $4,200 annually** across the project acres. The ERS methodology considers other economic benefits associated with a reduction in soil erosion, including soil productivity. Therefore, the valuation included here likely represents an underestimate of the total ecosystem service benefits associated with reduced soil erosion.

Value of additional water storage in improved soils.
Higher levels of SOM allow soils to hold additional water. For each percent increase in SOM, Arkansas soil scientists report that soil can hold an additional 16,500 gallons of plant-available water per acre-foot of soil (Sullivan 2002; USDA n.d.; Scott et al. 1986). While not specific to conditions in California, we can apply this conversion factor to approximate the water storage benefits of added SOM. Applying the increased SOM from CCI demonstrate plots after three years, we find a potential annual increase in plant-available water from improved soil health of **360 million gallons, equivalent to 1,100-acre feet,** across the projects.[25]

There are various ways that these additional gallons of water can be valued. One way involves applying available data on the shadow prices of water – developed by researchers at UC Davis using a model known as the California Value Integrated Model (CALVIN) – to physical quantities of water saved in various use categories.[26] Shadow prices are willingness-to-pay (WTP) measures that generally reflect the economic value for a good or service whose value is difficult to calculate and not reflected in the market.[27] Research utilizing the CALVIN model identifies that the average WTP to avoid a 5 percent water shortage for agricultural purposes ranges across regions in the state, varying from $79 per acre foot in the San Francisco Bay Area to $272 per acre foot in the South Coast (De Souza et al. 2011). By

[24] Avoided municipal water treatment costs are associated with consumer and producer surplus gains due to lower sediment removal cost for water treatment plans. Avoided municipal and industrial water use is associated with reduced damages from salts and minerals dissolved from sediment. See Hansen and Ribaudo (2008b) for details.

[25] Additionally, CCI projects located over aquifers have the potential to recharge groundwater aquifers. These potential benefit streams are not considered in this analysis and would represent an additional ecosystem service benefit stream.

[26] The CALVIN model is an economic-engineering optimization model for California specifically. Details about the model are available here: https://calvin.ucdavis.edu/.

[27] From an economic perspective, WTP is a conceptually appropriate measure of value of a resource or service. WTP is the maximum amount of money an individual would voluntarily exchange to obtain a resource or environmental improvement, given budget constraints. In other words, WTP indicates the point at which the individual would be equally satisfied with having the good itself or with having the money to spend on other things.

applying these regional estimates to the areas where projects in this category are located, we estimate a total WTP of approximately **$140,000** associated with additional water storage in soils from the implementation of on-farm conservation management practices.

Water also has a value if left in the ground for use by future generations. Fossil groundwater is a type of groundwater located deep beneath the surface that is considered a non-renewable resource because it takes thousands of years for the groundwater in these 'ancient aquifers' to recharge. The Lawrence Livermore National Laboratory recently released a study that examined 2,330 drinking wells and found evidence of fossil groundwater in 22 percent of wells (de Jong et al. 2020). To the extent that CCI projects are generating water savings in areas that overlap fossil groundwater resources, the benefits of the water savings associated with such projects may be better reflected by a bequest or option value because it reduces the pressure on these non-renewable groundwater resources.[28]

Value of fish habitat improvements.
Aquatic species are sensitive to changes in soil conditions near waterways. Factors such as stream discharge, nutrient content, and sediments can affect the ecological conditions in fish habitat. Studies by Keitzer et al. (2016a, 2016b) model how greater erosion control and nutrient management on agricultural fields improve the Fish Index of Biotic Integrity (fish IBI), a measure of ecological conditions based on fish populations, in waterways near agricultural sites in the Lake Erie Basin. Under specific erosion control and nutrient management assumptions, they estimate that fish IBI can improve 6 percent relative to baseline conditions. While studies from California demonstrate that fish habitat and communities are sensitive to environmental conditions, including the influence of agriculture (e.g., Brown 2000), they do not offer specific information about how fish IBI improves under specific agricultural management regimes, including those promoted by CCI. For demonstration purposes, this analysis considers a range of possible increases in fish IBI based on one percent and 6 percent increase in fish IBI scenarios relative to pre-project levels.

Johnston et al. (2011) find that households in Rhode Island were willing to pay $1.50 per year for each percentage point increase in fish IBI. We assume that watersheds categorized as Hydrologic Unit Code (HUC) 12 abutting the project areas experience these improvements in fish IBI and that households within these affected watersheds value ecological improvements within nearby fish habitat (USGS n.d.; County of Los Angeles 2022).[29] Our GIS analysis overlaying Census metrics atop a spatial layer of HUC-12 watersheds identifies 1.2 million households within 207 watersheds containing projects, equivalent to about 9 percent of all households in the state. Applying the valuation from Johnston et al. (2011) to each of the households in the watersheds abutting project areas for both fish IBI increase scenarios, we estimate a total potential benefit ranging from **$1.7 million to $10 million** per year.

Value of increased agricultural production from pollinator services.
Some of the CCI projects in this category increase pollinator habitat near or on cropland, which has the potential to improve yields of crops dependent on pollinator services.[30]

[28] Bequest value is the value people place on maintaining or conserving a resource for future generations. Option value is the WTP for a resource even though there is little or no likelihood the individual will use it.

[29] HUC-12 represents a local sub-watershed level that captures tributary systems. There are approximately 90,000 HUC-12 watersheds nationwide (EPA n.d.), and 4,500 in California specifically (California Nature 2021).

[30] Specific program activities that increase pollinator habitat include but are not limited to planting hedgerows, riparian buffers, trees, cover crops, and field borders.

Following the methodology in a study by Walston et al. (2018), we assume that highly pollinator-dependent crops within 1.5 kilometers (km) of added pollinator habitat may experience a one percent increase in crop yields.[31] Pollinator-dependent crops found near the 5,700 acres of pollinator habitat added by CCI projects include almonds; fruits such as apples, nectarines, berries, and melons; and vegetables including cucumbers, squash, and pumpkins (USDA NASS CropScape; California DWR Statewide Crop Mapping).[32] GIS analysis reveals that over 45,000 acres of highly dependent pollinator crops are within 1.5km of pollinator habitat added through these projects across 27 counties, and that the majority of these acres are cultivated with almonds (87 percent), plums (5 percent), and cherries (3 percent). Counties with the greatest acreage of pollinator-dependent almond crops within the buffer include Merced, Fresno, and Yolo counties.

We determine baseline productivity using average crop yields per acre for each crop across California (USDA 2023). The one percent increase in productivity is applied to these baseline acres by county to estimate the increase in crop output of approximately 827,000 kilograms of pollinator dependent crops. To value this increase in production, we apply California-specific commercial sales price per kg for each type of crop (USDA 2023; CDFA 2021). Combined the total commercial value of the increased production of pollinator-dependent crops from increased pollinator habitat may be approximately **$2 million**.

Improved regional food security.
Implementing conservation management practices that improve agricultural productivity also supports California's regional food security. By increasing agricultural production, these projects may reduce California's vulnerability to agricultural supply shocks and the need to source food from elsewhere. Research also indicates that a reduction in pollinator habitat and populations may create challenges for global food security (e.g., Bauer and Wing 2010). These projects generate pollinator habitat that may help to counteract observed global declines in pollinators and food security linked with their services.

Services associated with habitat for other species.
Employing nature-friendly field conservation management practices by installing vegetative buffers around fields can result in the added benefit of increasing the presence of birds and other species. Since vegetative buffers can serve as bird habitat, planting them can increase local bird populations. For example, one project documented that bird sightings increased by 27 percent between 2019 and 2020 after planting one mile of riparian restoration (CDFA 2021). Birds offer several ecosystem service benefits, including pest control, pollination, and waste disposal, among others (Şekercioğlu 2017).

[31] We use a conservative estimate of crop yield increases from pollinator services from the literature in order to account for uncertainty. Other studies, such as Blaauw and Isaacs (2014), estimate increases in crop yield from pollinator services of up to 30 percent after ten years.

[32] To determine which crops are pollinator-dependent, we rely on the characterization in Walston et al. (2018). In the supplemental materials, the authors provide pollinator dependence categories by crops produced across the United States. Consistent with their methods, we include all crops ranked 3 and 4, the highest two categories, in this analysis. The ranking in Walston et al. relied on information from Aizen et al. (2009) and Calderone (2012).

Table 4: Summary of Monetized Ecosystem Service Benefits for the On-Farm Conservation Management Projects by County (2021 dollars)

County	Total Acres with Improved Soil Practices[a]	Total Acres of New Pollinator Habitat[a]	Value of Nutrient Supply (Annual)[b]	WTP for Avoided Water Treatment Costs (Annual)[b,c]	Value of Water Supply (Annual)[b]	WTP for Improved Fish Habitat (Annual)[b,c]	Value of Increased Agricultural Production (Annual)[b]
Alameda	1,100	--	$70,000	<$100 - $130	$2,700	$150 - $880	--
Amador	240	61	$15,000	<$100	$1,100	$450 - $2,700	$4,100
Butte	3,000	140	$180,000	$200 - $340	$9,000	$130,000 - $770,000	$190,000
Colusa	1,800	180	$110,000	$120 - $200	$5,300	$11,000 - $64,000	$77,000
Contra Costa	170	--	$10,000	<$100	$400	$9,000 - $54,000	--
Del Norte	130	--	$7,900	<$100	$640	$3,700 - $22,000	--
El Dorado	51	45	$3,100	<$100	$160	$16,000 - $96,000	$880
Fresno	1,400	530	$86,000	<$100 - $160	$6,300	$210,000 - $1,200,000	$430,000
Glenn	610	260	$37,000	<$100	$1,900	$3,100 - $19,000	$22,000
Humboldt	280	71	$17,000	<$100	$1,400	$8,700 - $52,000	--
Imperial	1,100	--	$66,000	<$100 - $120	$5,200	$52,000 - $310,000	--
Kern	1,300	480	$77,000	<$100 - $140	$5,700	$170,000 - $1,000,000	$34,000
Kings	810	410	$49,000	<$100	$3,600	$13,000 - $81,000	$46,000
Lake	8	--	$490	<$100	<$100	$360 - $2,200	--
Madera	410	210	$25,000	<$100	$1,900	$21,000 - $130,000	$160,000
Marin	530	210	$32,000	<$100	$1,300	$4,100 - $25,000	$330
Mariposa	--	--	--	--	--	$810 - $4,900	--
Mendocino	180	110	$11,000	<$100	$870	$4,500 - $27,000	<$100
Merced	1,400	470	$84,000	<$100 - $160	$6,200	$69,000 - $420,000	$450,000
Modoc	440	30	$27,000	<$100	$1,300	$160 - $940	--
Monterey	20	11	$1,200	<$100	$130	$33,000 - $200,000	$540
Napa	40	26	$2,400	<$100	<$100	$33,000 - $200,000	$570
Nevada	17	14	$1,000	<$100	<$100	$990 - $5,900	--
Orange	1	1	<$100	--	<$100	$71,000 - $420,000	--
Placer	--	--	--	--	--	$28,000 - $170,000	--
Riverside	25	9	$1,500	<$100	$120	$14,000 - $81,000	--

County	Total Acres with Improved Soil Practices[a]	Total Acres of New Pollinator Habitat[a]	Value of Nutrient Supply (Annual)[b]	WTP for Avoided Water Treatment Costs (Annual)[b,c]	Value of Water Supply (Annual)[b]	WTP for Improved Fish Habitat (Annual)[b,c]	Value of Increased Agricultural Production (Annual)[b]
Sacramento	110	40	$6,800	<$100	$340	$42,000 - $250,000	$18,000
San Benito	230	--	$14,000	<$100	$1,500	$11,000 - $65,000	--
San Diego	910	3	$56,000	<$100	$7,500	$35,000 - $210,000	--
San Joaquin	160	97	$10,000	<$100	$500	$63,000 - $380,000	$98,000
San Luis Obispo	1,100	60	$66,000	<$100 - $120	$6,900	$62,000 - $370,000	$760
Santa Barbara	150	53	$9,100	<$100	$950	$76,000 - $450,000	$1,900
Santa Clara	200	--	$12,000	<$100	$480	$72,000 - $430,000	--
Santa Cruz	32	2	$2,000	<$100	$200	$11,000 - $67,000	$18,000
Shasta	600	--	$37,000	<$100	$1,800	$140 - $830	--
Solano	1,300	280	$81,000	<$100 - $150	$4,100	$53,000 - $320,000	$43,000
Sonoma	520	230	$31,000	<$100	$1,200	$140,000 - $810,000	$1,200
Stanislaus	380	130	$23,000	<$100	$1,700	$58,000 - $350,000	$130,000
Sutter	6,900	63	$420,000	$470 - $780	$21,000	$17,000 - $100,000	$44,000
Tehama	750	74	$46,000	<$100	$2,300	$6,400 - $38,000	$13,000
Tulare	2,400	600	$150,000	$170 - $270	$11,000	$52,000 - $310,000	$160,000
Ventura	85	7	$5,200	<$100	$700	$35,000 - $210,000	<$100
Yolo	2,600	830	$160,000	$180 - $300	$7,900	$80,000 - $480,000	$220,000
Yuba	3,400	--	$200,000	$230 - $380	$10,000	$10,000 - $63,000	--
Statewide Total	**37,000**	**5,700**	**$140,000,000**	**$2,500 - $4,200**	**$140,000**	**$1,700,000 - $10,000,000**	**$2,200,000**

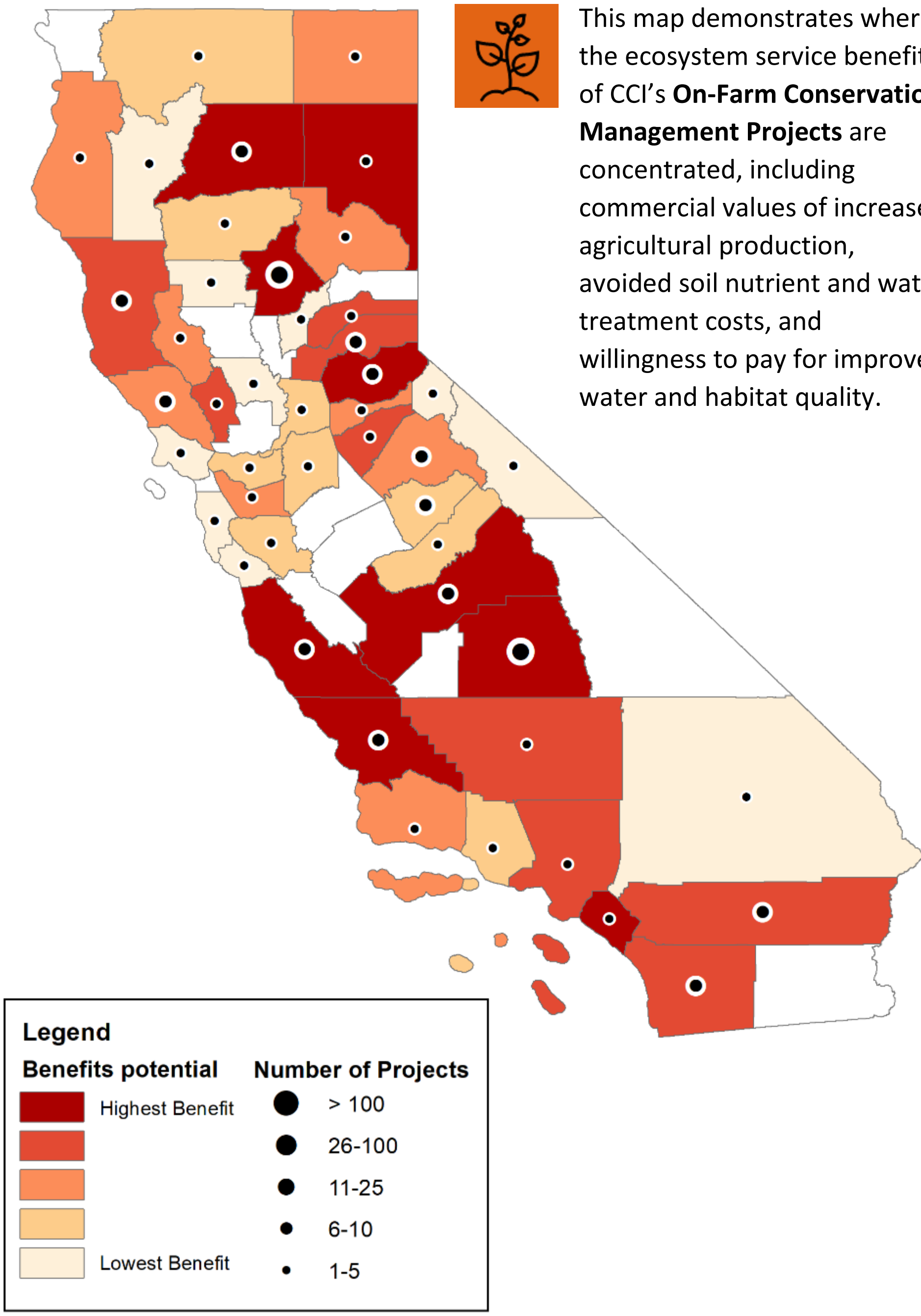
Sources and notes:

a. Data observed in CARB (2021) considering projects implemented from 2018 to 2020.

b. Author calculations described in this report. The monetary values presented in this table are not necessarily additive to a single, total benefits value as they reflect alternative valuation methods and measures (e.g., market values, social welfare values) and may double-count the same benefit stream.

c. When "<$100" is used to express the low-end of a range, the expected value of the metric is between a value less than $100 and the high-end value. When "<$100" is used to express the entirety of a range, both the low-end and high-end values of the metric are less than $100.

Figure 4: Spatial Distribution of Ecosystem Service Benefits Potential for the On-Farm Conservation Management Projects



This map demonstrates where the ecosystem service benefits of CCI's **On-Farm Conservation Management Projects** are concentrated, including commercial values of increased agricultural production, avoided soil nutrient and water treatment costs, and willingness to pay for improved water and habitat quality.

Note: The benefit potential conveyed in this map considers all five monetized values presented in Table 4. For the two categories expressed as a range, the high-end value is included.

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AGRICULTURE

Increasing Efficiency of Agricultural Irrigation

Ecosystem Service Benefits

- Improved efficiency in water use results in reduced need for water supply maintenance and avoided property damage through reduced subsidence.
- The potential magnitude of benefits resulting from reduced water supply maintenance needs is on the order of $15 million per year.
- Replacing pumps with more energy efficient options also increases local air quality and improves human health.

OVERVIEW OF PROJECTS

Project activities
Implement more efficient strategies to reduce on-farm water and energy use

Implementing agency
California Department of Food and Agriculture

598 projects
across 33 counties (2015-2018)

36 billion
gallons of water saved annually

The California Department of Food and Agriculture (CDFA)'s State Water Efficiency and Enhancement Program (SWEEP) aims to boost energy and water efficiency practices on farms, mostly in the form of upgrading agricultural irrigation systems. Examples of irrigation system upgrades supported by CCI include soil moisture monitoring, drip systems, low pressure irrigation systems, pump retrofits, variable frequency drives and installation of renewable energy to reduce on-farm water use and energy. Between 2015 and 2018, CDFA implemented a total of 598 SWEEP projects across 33 counties (CARB 2021). The four counties with more than 50 projects each are Butte, Fresno, San Luis Obispo, and Tulare.

While the energy and greenhouse gas emissions benefits of these projects are considerable, they are outside the scope of this analysis. This analysis focuses on the ecosystem services specifically associated with improved water efficiency. Appendix page A-4 describes the pathways through which these projects generate environmental changes as well as ecosystem service benefits. Improved efficiency in water use is valued both by the agricultural industry and the general public. Improved irrigation efficiency is also linked to avoided property damage, as excessive groundwater pumping can lead to costly land subsidence. Human health benefits can also be expected for the subset of projects that involve retrofitting electric pumps that result in local air quality improvements.

Avoided water supply maintenance.
Increased efficiency of irrigation systems leads to a reduction in water needs. These projects report nearly 36 billion gallons of water saved each year, equivalent to about 110,000 acre-feet.[33,34,35]

There are various ways that these additional gallons of water can be valued. One way involves applying available data on the shadow prices of water – developed by researchers at UC Davis using a model known as the California Value Integrated Model (CALVIN) – to physical quantities of water saved in various use categories.[36] Shadow prices are willingness-to-pay (WTP) measures that generally reflect the economic value for a good or service whose value is difficult to calculate and not reflected in the market.[37] Research utilizing the CALVIN model identifies that the average WTP to avoid a 5 percent water shortage for agricultural purposes ranges across regions in the state, varying from $79 per acre foot in the San Francisco Bay Area to $272 per acre foot in the South Coast (De Souza et al. 2011). This analysis finds that the potential water savings associated with improved irrigation practices are valued at approximately **$15 million per year.**

[33] 'Acre foot' is a term commonly used in water supply planning to describe water volume. An acre foot is approximately 326,000 gallons, which is enough water to cover an acre of land (about the size of a football field) about 1-foot deep. According to the Water Education Foundation, an average California household uses between one-half and one acre-foot of water per year for indoor and outdoor use. (Source: https://www.watereducation.org/general-information/whats-acre-foot)

[34] The project implementers report total water gallons saved throughout the life of the project. Most projects are associated with 10-year life spans, although a subset last 15as long as 100 years. To calculate an annual water savings quantity, we divide the total water savings reported by the project lifetime.

[35] While large in magnitude, 110,000 million acre-feet is equivalent to about 0.3 percent of all water used for agricultural purposes in California annually (CARB 2022).

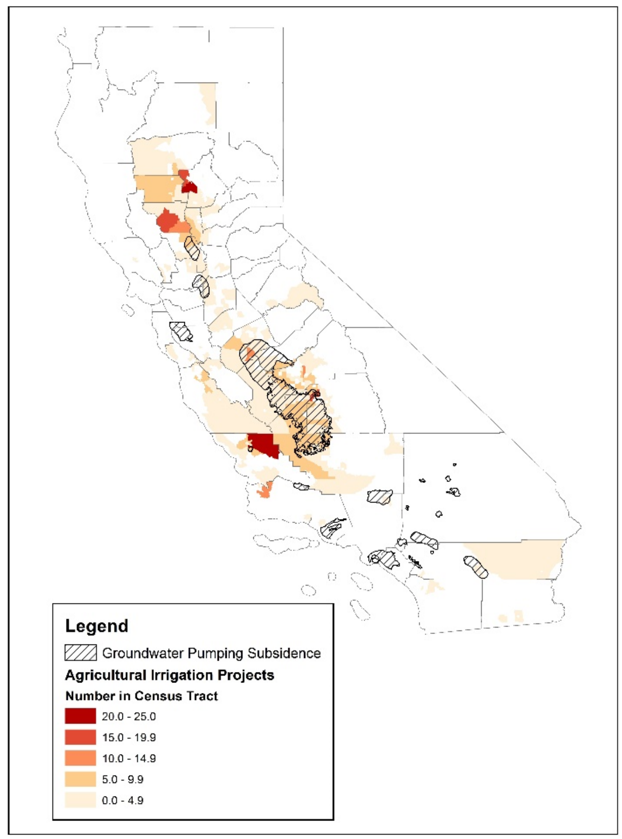
[36] The CALVIN model is an economic-engineering optimization model for California specifically. Details about the model are available here: https://calvin.ucdavis.edu/.

[37] From an economic perspective, WTP is a conceptually appropriate measure of value of a resource or service. WTP is the maximum amount of money an individual would voluntarily exchange to obtain a resource or environmental improvement, given budget constraints. In other words, WTP indicates the point at which the individual would be equally satisfied with having the good itself or with having the money to spend on other things.

Water also has a value if left in the ground for use by future generations. Fossil groundwater is a type of groundwater located deep beneath the surface that is considered a non-renewable resource because it takes thousands of years for the groundwater in these 'ancient aquifers' to recharge. The Lawrence Livermore National Laboratory recently released a study that examined 2,330 drinking wells and found evidence of fossil groundwater in 22 percent of wells (de Jong et al. 2020). To the extent that CCI projects are generating water savings in areas that overlap fossil groundwater resources, the benefits of the water savings associated with such projects may be better reflected by a bequest or option value because it reduces the pressure on these non-renewable groundwater resources.[38]

Avoided property damage from reduced land subsidence. For subset of projects located in the San Joaquin Valley, another potential benefit of water savings is the avoided costs associated with land subsidence, which is the gradual or sudden sinking of the land's surface. Groundwater pumping from any aquifer "will cause some degree of land subsidence as aquifer materials adjust to new stresses" (Borchers and Carpenter 2014). Excessive groundwater pumping can cause damage to property and infrastructure. In the San Joaquin Valley, USGS has conducted subsidence studies in California since the 1950s and has recorded land subsidence of as much as 30 feet in some areas. The rate of subsidence, however, is increasing in some areas. For example, during the latest drought, hydrologists recorded subsidence rates in the San Joaquin Valley of more than a foot per year (McPhate 2017). Of the 598 SWEEP projects, 128 overlap an area of land subsidence caused by groundwater pumping (USGS n.d.). This analysis cannot quantify this benefit because there is limited information on the role these projects play in mitigating subsidence.

Figure 5: CCI Project and Subsidence Locations



Improved human health from localized air quality improvements. The pumps used for irrigation can degrade air quality through the release of pollutants such as oxides of nitrogen and volatile organic compounds resulting in the formation ground level ozone (Lu et al. 2016) as well as particulate matter and an array of other pollutants. Retrofitting the pumps used for irrigation purposes has the potential to improve localized air quality by reducing these emissions. This is especially true for projects that reduce diesel fuel combustion. Improved air quality can also benefit human health. SWEEP projects do not monitor local air quality conditions associated

[38] Bequest value is the value people place on maintaining or conserving a resource for future generations. Option value is the WTP for a resource even though there is little or no likelihood the individual will use it.

with pump upgrades and therefore we are unable to monetize the reduction in health impacts associated with improvements in local air quality at these project sites.

Table 5: Summary of Monetized Ecosystem Service Benefits for the Increasing Efficiency of Agricultural Irrigation Projects by County (2021 dollars)

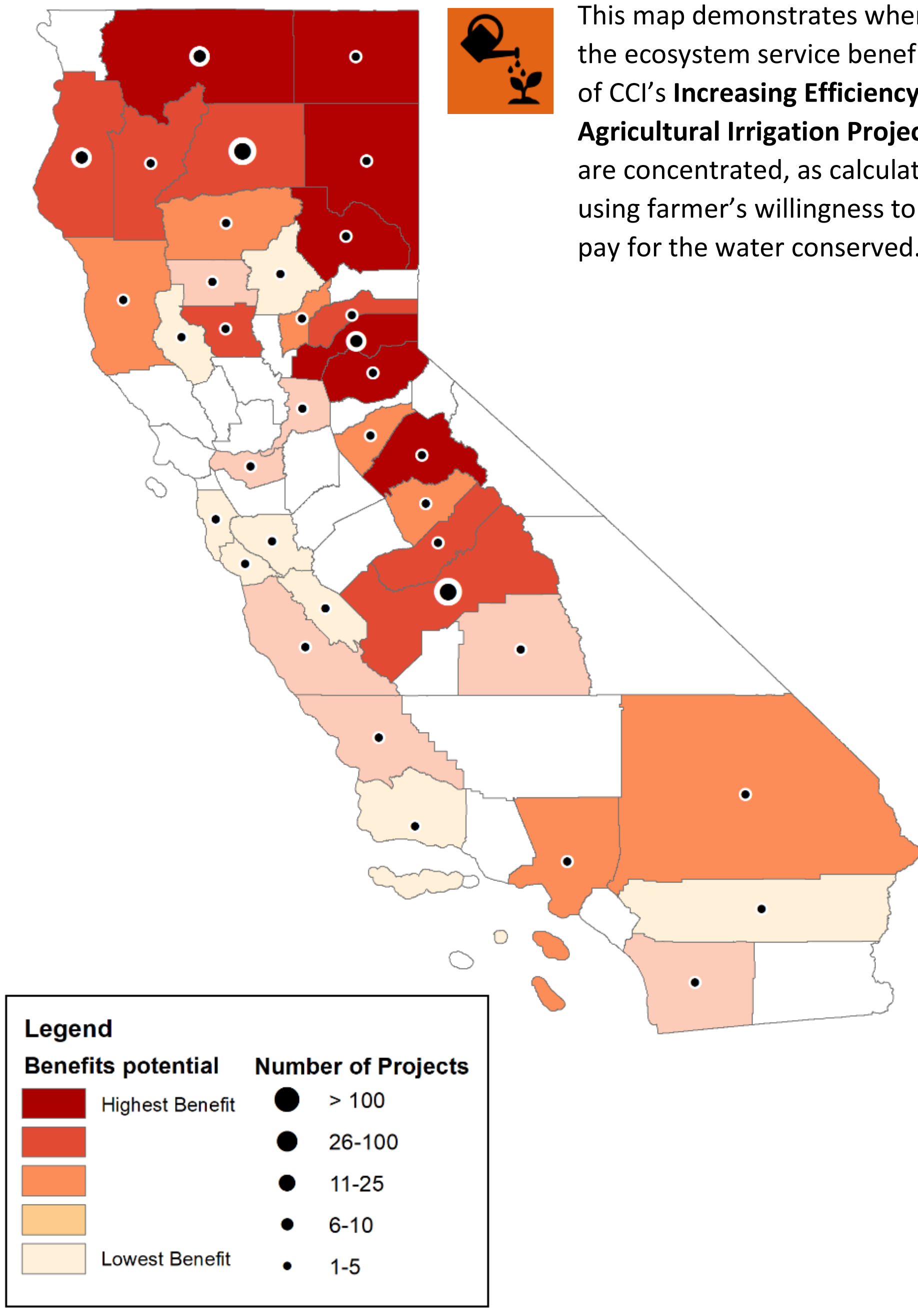
County	Acre-Feet of Water Saved (Annual)[a]	WTP for Water Saved (Annual)[b]
Butte	1,800	$180,000
Colusa	6,200	$620,000
Contra Costa	<1	<$100
Fresno	28,000	$4,100,000
Glenn	1,400	$140,000
Imperial	110	$18,000
Kern	12,000	$1,700,000
Kings	13,000	$1,900,000
Los Angeles	<1	<$100
Madera	1,200	$180,000
Merced	6,800	$1,000,000
Monterey	1,200	$250,000
Napa	41	$3,200
Riverside	430	$67,000
Sacramento	490	$49,000
San Benito	61	$13,000
San Diego	220	$59,000
San Joaquin	7,400	$740,000
San Luis Obispo	970	$200,000
Santa Barbara	660	$140,000
Santa Clara	530	$42,000
Santa Cruz	69	$14,000
Shasta	45	$4,600
Solano	280	$28,000
Sonoma	1	<$100
Stanislaus	350	$51,000
Sutter	3,500	$350,000
Tehama	250	$25,000
Tulare	21,000	$3,100,000
Tuolumne	4	$600
Ventura	19	$5,100
Yolo	1,600	$160,000
Yuba	470	$47,000
Statewide Total	**110,000**	**$15,000,000**

Sources and notes:

a. Data observed in CARB (2021). The annual average considers projects implemented from 2015 to 2018.

b. Author calculations described in this report.

Figure 6: Spatial Distribution of Ecosystem Service Benefits Potential for the Increasing Efficiency of Agricultural Irrigation Projects



This map demonstrates where the ecosystem service benefits of CCI's **Increasing Efficiency of Agricultural Irrigation Projects** are concentrated, as calculated using farmer's willingness to pay for the water conserved.

Note: The benefit potential conveyed in this map considers farmers' WTP for the water saved presented in Table 5.

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AGRICULTURE

Alternative Manure Management

Ecosystem Service Benefits

- Sustainable manure management and compost production is associated with benefits related to soil health, odor reduction, and improved human health.
- Consumers are willing to pay a premium for milk produced in more environmentally sustainable conditions. The public may value the environmental attributes of the milk produced by dairy cows as a result of these projects on the order of $467 million per year.
- Property values could increase by $880,000 on an annualized basis near project sites due to reduced odor.
- The market value of compost produced in 2020 was $430,000. The application of composted manure to fields is estimated to result in benefits of up to $19 million in safer drinking water per year and $3,000 in plant-available water storage.

OVERVIEW OF PROJECTS

Project activities
Implement projects using anaerobic digestion and other methods for more sustainable manure management

Implementing agency
California Department of Food and Agriculture

210 projects
funded across 14 counties (2015-2020)

430,000 dairy cows
with manure managed more sustainably

36,000 yards^3 compost
produced annually

Between 2015 and 2020, the California Department of Food and Agriculture (CDFA) funded 104 projects as part of its Alternative Manure Management Program (AMMP) and 106 projects as part of its Dairy Digester Research and Development Program (DDRDP), which both implement activities related to the handling and storing manure with and without the use of an anaerobic digester.[39] The projects in this category are found across 14 counties (CARB 2021), with the highest concentration in Tulare County. Methods of manure management include pasture-based management, compost bedded pack barns, solid separation, conversion of flush to scrape manure collection systems, and the use of anaerobic digesters. All projects in this category require methods other than manure storage in open and uncovered lagoons. As part of their monitoring efforts, the projects additionally measure the amount of compost produced (if applicable), which can either be used on the farm or sold for use elsewhere.

Improved manure handling leads to ecological changes such as improvements in water quality from reduced nutrient loss. Other environmental benefits of improved manure management include reduced odor and improved local air quality. Appendix page A-5 describes the pathways through which these projects generate environmental changes as well as ecosystem service benefits. Improved manure management strategies are linked to ecosystem service benefits in this analysis using valuations of compost production, improved human health from higher quality drinking water, and increased property values from odor reductions. These values are calculated using data from the CDFA's AMMP and DDRDP Benefits Calculator Tools and are based on methods and assumptions found in the relevant literature.[40] We also qualitatively characterize the pathways to improved human health from local air quality improvements and reduced pathogens as well as the positive preference people have for improved water quality.

Willingness to pay (WTP) to for milk produced with higher environmental standards.[41] Research demonstrates that people are willing to pay a higher price for agricultural products produced with greater consideration of environmental sustainability. For instance, one study finds that consumers in California are willing to pay a $0.40 per pound premium for food produced at a higher environmental standard of sustainability, defined as products which result in lower greenhouse gas emissions (Campbell 2021). For demonstration purposes, we apply this WTP for milk produced at CCI project sites.[42]

[39] For simplicity, we refer to this broader project category as "Alternative Manure Management," which includes both the AMMP and DDRDP projects. In this category, we explore the combined benefits of AMMP and DDRDP projects, both of which focus on sustainable agricultural manure management practices. DDRDP has additional co-benefits related to renewable energy generation via anaerobic digestion, but these benefits are captured as part of the GHG methodology. Instead, we evaluate the ecosystem service benefits related to improved manure handling specifically across the AMMP and DDRDP projects.

[40] The CCI Benefits Calculators were constructed primarily to estimate the GHG emission reduction and select co-benefits for reporting to CARB. All benefits calculators can be found online at: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. This analysis incorporates data from completed calculator tools provided by CDFA (CDFA 2021).

[41] From an economic perspective, WTP is a conceptually appropriate measure of value of a resource or service. WTP is the maximum amount of money an individual would voluntarily exchange to obtain a resource or environmental improvement, given budget constraints. In other words, WTP indicates the point at which the individual would be equally satisfied with having the good itself or with having the money to spend on other things.

[42] For context, related research demonstrates that consumers are willing to pay for milk produced under higher animal welfare standards (Wolf and Tonsor 2017). Wolf and Tonsor find that households are willing to pay greater than $0.40 per gallon of milk for *each* welfare attribute described in their survey, suggesting that applying the WTP value from Campbell (2021) to milk produced at CCI project sites is unlikely to be an over-estimate.

The CCI projects in this category are home to approximately 430,000 dairy cows as of 2020 (CDFA 2021), and research demonstrates that dairy cows produce a national average of 2,700 gallons of milk per year (NASS 2020).[43] Combined the dairy cows at these project sites produce about **1.2 billion gallons** of milk per year.[44] If we assume consumers are willing to pay an additional $0.40 per pound for this milk, then this analysis finds that California consumers may value the various environmental benefits of improved manure management practices on the order of **$470 million per year**.

Increased property values from odor reduction.
Odor from livestock facilities has been shown to negatively affect property values (Ready and Abdalla 2003). Anaerobic digestion, one of the practices promoted by these projects, reduces the odor from waste by processing its biodegradable parts. For example, Wilkie et al. (2005) show that flushed dairy manure after anaerobic digestion decreases odor by 97 percent relative to flushed dairy manure that does not undergo anaerobic treatment. Although the available literature does not describe the WTP for odor reduction specifically, we draw upon studies linking changes in property value to proximity to livestock facilities with high odor in order to estimate the potential magnitude of property value increases from odor reduction in project areas. Ready and Abdalla (2003) find that being located near animal production facilities in Berks County, Pennsylvania leads to a 6.4 percent decrease in housing price for houses within 500 meters of facilities; a 4.1 percent decrease in property value for houses within 800 meters of facilities; and a 1.6 percent decrease in value for houses within 1,200 meters of facilities.

To apply these findings to this analysis, we first count the number of unique land parcels within each buffer from AMMP and DDRDP project sites (County of Los Angeles 2022). Across the 14 counties with projects, 684 parcels were counted within 500 meters; 470 within 800 meters; and 2,404 within 1,200 meters. We determine baseline property values by county using data from the U.S. Census Bureau (2021), then apply the change in property values from Ready and Abdalla (2003), but in the opposite direction: we assume property value increases when odor is reduced. Combined, the potential property value increase from odor reduction across buffer sizes may be $29 million in present value terms, equivalent to **$880,000 on an annualized basis** (with a 3 percent discount rate). Forty-three percent of the estimated property value increase is attributed to the properties within closest range of the project areas, followed by properties within a 1,200-meter buffer. Because this analysis considers a broader geographic coverage than just the project sites, select properties in Del Norte and Sacramento counties also experience this benefit.

Commercial market value of compost.
For some projects, changes in manure management practices result in production of composted manure for use as a soil amendment on agricultural fields.[45] Compost production data was documented for both AMMP and DDRDP in 2020 only. We assume 2020 is representative of typical compost production at these sites, although it is possible that compost application will increase

[43] NASS (2020) also demonstrates that dairy cows in California typically have higher efficiency than the national average.

[44] There are 1.72 million milk cows in California, therefore the dairy cows at CCI project sites represent about 25 percent of the state total (USDA NASS 2011). Similarly, California produced about 4.9 billion gallons of milk in 2021, meaning milk produced at CCI project sites could represent about 24 percent of all milk produced in the state (Statista 2022).

[45] CDFA reports that some project sites may use composted and dried manure as animal bedding as well. We do not separately value the use of composted manure as animal bedding.

among these project locations in the future. In 2020, 36,000 cubic yards of compost were produced from manure at project sites in five counties (CDFA 2021).[46] Composted manure can be used on nearby agricultural fields and potentially displace the need for other nutrients. Farmers with excess nutrients may choose to sell the compost to other farmers, representing an additional income stream. Applying a statewide estimated market price of $12 per cubic yard of compost produced (CalRecycle 2019), we value the total amount of compost produced at approximately **$430,000 per year**. Most the compost produced (70 percent) —worth $300,000—was in project areas in Stanislaus and Merced counties.

WTP for avoided nitrates in water.

Animal manure from agricultural operations is a primary source of nitrates in ground and surface water (EPA 2023).[47] Applying composted manure to fields instead of raw manure results in lower levels of nitrogen runoff that could enter nearby waterways and drinking water systems (Sustainable Conservation 2017). For instance, one study found that 9 percent of nitrogen is lost from applying uncomposted manure, while only 4 percent is lost from composted manure (Rodale Institute 2004). Similarly, upgrading the lagoons that capture and store animal manure (e.g., with liners or improved lagoon covers) has the potential to reduce nitrates in drinking water by keeping it on site. Available research is insufficient to value the human health benefits associated with this specific reduction in nitrogen runoff. Instead, we consider evidence showing that households in areas of Indiana, Nebraska, and Washington are willing to pay between $840 and $1,100 per year to avoid nitrates in their drinking water above EPA safe minimum levels (Crutchfield et al. 1997).[48]

[46] CDFA notes this is likely an under-estimate of the total composted manure produced by the projects.

[47] EPA (2023) estimates that California agriculture contributes nearly 3,200 kgs of nitrogen from animal manure per square kilometer.

[48] EPA's maximum contaminant level (MCL) for nitrate set to protect against blue-baby syndrome is 10 mg/L.

Most agricultural areas in California are surrounded by groundwater wells that support drinking water.[49] Wells sampled in only two of the 14 counties with AMMP and DDRDP projects—Kern and Tulare—recently have been observed to contain nitrogen levels above EPA safe standards (State Water Resources Control Board 2017).[50] Therefore, households in these two counties are the most likely to benefit from any potential reduction in nitrates in drinking water due to project activities. These two counties also contain many projects in this category: 53 projects in Tulare and 17 projects in Kern. The CCI projects in these two counties may reduce nitrate levels, contributing to the ability of the water sources to meet EPA safe standards. Crutchfield et al. (1997) find that the value meeting these standards to the 17,000 households in Census tracts containing AMMP and DDRDP project sites in Kern and Tulare counties may be on the order of $14 million to $19 million per year.[51] This value represents the benefits to the residents of achieving safe standards as opposed to the specific benefits of the CCI projects; however, the CCI project improve the likelihood of the water quality improvements.

Positive preference for improved ambient and surface water quality. Improvements in manure management are also associated with improvements in surface and ambient water conditions (Aillery et al. 2005). Reducing nitrate runoff through these practices has the potential to improve water and habitat quality for aquatic species. Several studies demonstrate people have a WTP to improve ambient and surface water quality (e.g., Von Houtven et al. 2007) given the many ecosystem services clean surface water provides: improved water-based recreation opportunities (like boating, swimming, and fishing), increased populations of fish targeted for recreational and commercial fishing, and better aesthetics. Larson et al. (2001) provides estimates specific to households in California and found that the average household in their survey sample was willing to pay about $15 per month (1997 dollars) for a program that would raise water quality in water bodies throughout the state to levels that would be in compliance with clean water laws. Improvements in water quality resulting from these CCI projects are likely to be more modest, however data are not available to quantify or model these changes.

Value of additional water storage in soils treated with composted manure. Some of the project sites use the composted manure on their fields, either fields that support fodder for livestock or crop agriculture. Compost application improves soil health through increased soil organic matter (SOM). As described elsewhere for CCI projects that implement on-farm field conservation management practices, higher levels of SOM enable soils to retain more water. The literature describes that for each percent increase in SOM, soils hold an additional 16,500 gallons of plant-available water per acre-foot of soil (Sullivan 2002; USDA n.d.; Scott et al. 1986). Assuming the SOM levels of these fields respond similarly to the fields as part of the On-Farm Conservation Management Practices projects, which includes fields treated with compost, data from those projects shows average increases in SOM of 0.15 percent after one year, 0.20 percent after two years, and 0.60 percent after three years. In 2020, the only year with compost application data available for both AMMP and DDRDP, compost was applied to a total of 571 acres in five counties across 15 projects (7 percent of total) (CDFA 2021). Applying the increase in water retention among fields with higher SOM, this analysis

[49] See for example: https://www.waterboards.ca.gov/gama/well_location_information.html.

[50] It is possible that more recent data would reveal other counties with high nitrate levels. The 2017 report was the most recently available for use in this assessment.

[51] These household represent one percent of total households in Kern County and 9 percent of all households in Tulare County (U.S. Census data).

finds that compost application at these project sites retains approximately 5.6 million gallons of water in the soil after three years of application.

There are various ways that these additional gallons of water can be valued. One way involves applying available data on the shadow prices of water – developed by researchers at UC Davis using a model known as the California Value Integrated Model (CALVIN) – to physical quantities of water saved in various use categories.[52] Shadow prices are WTP measures that generally reflect the economic value for a good or service whose value is difficult to calculate and not reflected in the market. Research utilizing the CALVIN model identifies that the average WTP to avoid a 5 percent water shortage for agricultural purposes ranges across regions in the state, varying from $79 per acre foot in the San Francisco Bay Area to $272 per acre foot in the South Coast (De Souza et al. 2011). Applying this valuation to the water savings from improved soil management, this analysis finds a potential total benefit of **$2,600** associated with increased water storage in soils with compost application. As additional project sites apply composted manure to their fields, the magnitude of this benefit is likely to increase.

Improved human health. Livestock waste may contain pathogens harmful to human health, including *Salmonella spp.*, *E.coli*, *Campylobacter spp.*, and *Cryptosporidium spp.* (Bicudo and Goyal 2003). Studies demonstrate that anaerobic digester systems substantially reduce E. coli levels (Wang and Pandey 2017) and other pathogens (Wilkie et al. 2005) on farm. These reductions may also reduce the likelihood of illness resulting from these pathogens, through exposures of farm staff, downstream consumers of food products that may come into contact with the manure, or via waterways connected to project sites. USDA's Economic Research Service modeled the cost of foodborne illness associated with these and other pathogens, finding that the average economic burden per case is on the order of thousands of dollars.[53]

Human health is also affected by manure's role in degrading localized air quality. When manure is stored, microorganisms decompose organic matter and release pollutants into the air, including volatile organic compounds, ammonia, hydrogen sulfide, and particulate matter (Zhang 2011). These pollutants can cause a range of health effects, including skin and eye irritations, headaches, and nausea. Alternative manure management approaches incentivized by CCI have the potential to reduce these impacts. Workers that interact directly with the pollutants are likely to benefit most, although nearby communities may also experience health improvements. Data are not available to quantify the reduction in health impacts associated with changes at these project sites.

[52] The CALVIN model is an economic-engineering optimization model for California specifically. Details about the model are available here: https://calvin.ucdavis.edu/.

[53] The full set of USDA ERS's cost estimates for these and other foodborne illnesses is available at: https://www.ers.usda.gov/data-products/cost-estimates-of-foodborne-illnesses.aspx

Table 6: Summary of Monetized Ecosystem Service Benefits for the Alternative Manure Management Projects by County (2021 dollars)

County	Total Dairy Cows[a]	Cubic Yards of Compost Produced (Annual)[a]	Acres with Compost Application (Annual)[a]	WTP for Milk Produced with Environmental Standards (Annual)[b]	Increased Property Values from Odor Reduction (Annualized)[b]	Commercial Market Value of Compost (Annual)[b]	Value of Additional Water Storage (Annual)[b]
Del Norte	--	--	--	--	$1,200	--	--
Fresno	32,000	--	--	$35,000,000	$65,000	--	--
Glenn	600	--	--	$650,000	$4,900	--	--
Humboldt	550	--	--	$600,000	$25,000	--	--
Kern	67,000	4,600	56	$73,000,000	$8,200	$55,000	$250
Kings	49,000	--	--	$53,000,000	$33,000	--	--
Madera	4,300	2,200	54	$4,600,000	$13,000	$27,000	$240
Marin	450	--	--	$490,000	$6,600	--	--
Merced	80,000	5,100	95	$87,000,000	$260,000	$62,000	$430
Sacramento	--	--	--	--	$5,400	--	--
San Joaquin	7,100	--	--	$7,700,000	$120,000	--	--
Sonoma	440	--	--	$480,000	$42,000	--	--
Stanislaus	14,000	3,700	89	$30,000,000	$170,000	$44,000	$1,300
Tulare	160,000	4,100	78	$170,000,000	$130,000	$49,000	$350
Statewide Total	**430,000**	**36,000**	**571**	**$470,000,000**	**$880,000**	**$430,000**	**$2,600**

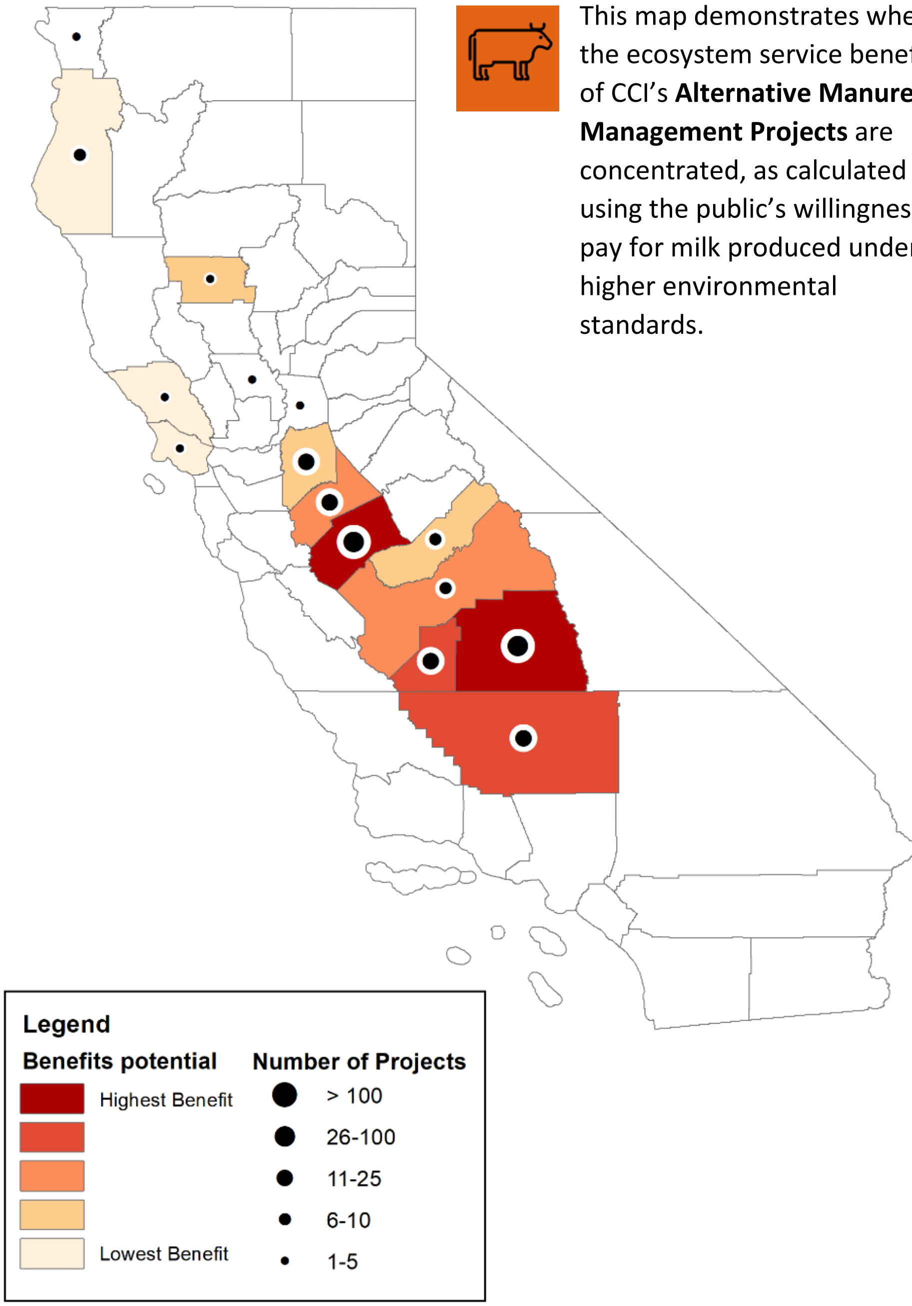
Sources and notes:

a. Data observed in CDFA (2021). The total dairy cows column considers all projects implemented from 2015 to 2020. The annual compost production and application figures are derived from 2020 data only.

b. Author calculations described in this report. The monetary values presented in this table are not necessarily additive to a single, total benefits value as they reflect alternative valuation methods and measures (e.g., market values, social welfare values) and may double-count the same benefit stream.

Figure 7: Spatial Distribution of Ecosystem Service Benefits Potential for the Alternative Manure Management Projects

This map demonstrates where the ecosystem service benefits of CCI's **Alternative Manure Management Projects** are concentrated, as calculated using the public's willingness to pay for milk produced under higher environmental standards.



Note: The benefit potential conveyed in this map considers the WTP for milk produced under higher environmental standards presented in Table 6.

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