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Opportunities and gaps in conservation incentive programs on California agricultural land

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Agricultural incentive programs promote ecosystem health and biodiversity on California working lands and encourage a multitude of conservation goals. The various objectives, environmental impacts, and financial costs of conservation incentive programs are challenging to assess. The ecosystem services framework is a useful tool for identifying tradeoffs between conservation management options. Here, 52 active incentive programs were reviewed to determine the ecosystem services prioritized by each program in California. Next, the top 20 highest funded federal conservation practices were assessed in terms of their ecosystem service impacts. We found that there is a gap between California's ecosystem services goals and the ecosystem services that are impacted by federal programs, and that the top funded practices are not necessarily the ones that deliver the best benefits in terms of ecosystem services. This study highlights the gaps between conservation goals and outcomes on California agricultural land, as well as the need for regional conservation monitoring to determine the impacts of incentive programs.

KEYWORDS

sustainable agriculture, ecosystem services, regenerative agriculture, incentive programs, multifunctional landscape, EQIP, agroecology, California

1. Introduction

The multiple and entwined planetary crises of climate change, accelerated biodiversity loss, dynamic demographics, and land degradation call for a significant and difficult transition from monofunctional food production systems towards multifunctional agroecological systems that provide ecosystem services, biodiversity restoration, and sociocultural enhancement (Renting et al., 2009; de Boon et al., 2022). Agriculture is the most widespread human-managed ecosystem on the planet and the conversion of natural ecosystems for crop and livestock production has contributed to cheap and reliable production of food and fiber (Foley et al., 2005). However, environmental degradation that results from removal of natural vegetation and the associated loss of biodiversity and ecological functions due to agricultural practices is also well-established (Bennett et al., 2009; Ramankutty et al., 2018; Newton et al., 2021). Intensive or high-input agricultural practices that incorporate fertilizers, pesticides, and soil degradation, and use or move large volumes of groundwater and surface water, have severe negative consequences for ecosystem health and other benefits humans derive from natural ecosystems. Due to its magnitude in terms of land use, agriculture is also recognized as a key driver of climate change and as a necessary part of any solution to reduce or sequester greenhouse gasses (Vermeulen et al., 2012).

Many research and policy trajectories argue for multidimensional approaches that make food provision sustainable, not only minimizing ecosystem destruction, but also regenerating ecosystem functions on existing agricultural land (Kremen et al., 2012; Martin and Isaac, 2018). These approaches include agroecology, regenerative agriculture, and multifunctional agriculture. Regenerative agriculture, a concept more prominent in the United States, is a systemic practice that focuses on rebuilding soil health, carbon sequestration, the integration of livestock, smallholder systems, and biodiversity enhancement (Newton et al., 2020; White, 2020). The House Committee on Oversight and Reform held a hearing on regenerative agriculture in July 2022, where farmers and experts in the field described the need for a transition to these practices (COA, 2022). The Inflation Reduction Act of 2022 provided $19.5 billion for "climate smart agriculture" in addition to the funding the farm bill provides. While widespread interest is evidenced for all the sustainable alternatives to industrial monofunctional agriculture, few legal, regulatory or even widespread definitions exist (Montenegro de Wit and Iles, 2016; Newton et al., 2020). All, however, emphasize soil and ecosystem restoration, dependence upon ecosystem function and biological interactions, integration of domestic plants and animals, and artful combination of annual and perennial plants (Tittonell et al., 2022).

Ecosystem services are the benefits provided by nature to people (Leemans and De Groot, 2003; IPBES, 2019), and the widespread loss of biodiversity due to land transformation and degradation has led to calls from governments and institutions to include ecosystem services in conservation planning (Egoh et al., 2007). Despite the growing interest in ecosystem services as a framework since its inception (De Groot, 1987; Costanza et al., 1997; Daily et al., 1997; Leemans and De Groot, 2003; IPBES, 2019), conventional farm policy in the United States has been slow to incorporate ecosystem services in agricultural management. However, financial incentives to promote ecosystem health and biodiversity on working lands do exist and encourage a multitude of conservation goals that can be tied to ecosystem services (Coleman and Machado, 2022). Federal and state incentive programs provide grants, technical assistance, financial assistance, tax credits, or easement contracts to private landowners in exchange for the voluntary adoption of certain conservation practices such as cover crops, irrigation management, and prescribed grazing (Stuart and Gillon, 2013). Previous work has described many of the factors influencing landowners' decision-making when it comes to conservation (Stuart, 2009; Merrill et al., 2011; Wong, 2021; Coleman and Machado, 2022), but with few exceptions (e.g., Coleman and Machado, 2022), very little work has been done to identify the ecosystem services targeted by these programs or to evaluate the ecosystem outcomes of the applied practices encouraged by the programs (Tomer and Locke, 2011; Herzog and Franklin, 2016; Eriksson et al., 2023).

In the United States, the fate of the ecosystems that overlap with farmland and the benefits they provide on and beyond the border of the farms depend on the decisions of private landowners, so incentive mechanisms are critical in convincing farmers to employ conservation practices. Ninety-eight percent of farms are owned by individuals and families, with 201.5 million acres of cropland and 223.8 million acres of grassland (range and pasture) (U.S. Census Bureau, 2017; Whitt et al., 2020). The State of California in particular is a critical agricultural hub in the U.S., consistently earning more than almost any other state in agricultural production. Simultaneously, the California Floristic Province is a global biodiversity hotspot with over 5,500 native plant taxa, 40% of which are endemic (Myers et al., 2000). California is a complex and interesting case study in the analysis of conservation incentive programs on working lands. Its contribution to national food security, as well as its incredible biodiversity, make California farmland critical to rural communities and municipal and state governments. Meanwhile, tradeoffs between these values depend on land management decisions made almost entirely by private landowners.

This study aims to provide an assessment of the ecosystem services encouraged by federal and state agricultural programs adopted by California farmers. We had two primary objectives: (1) to outline the extent to which ecosystems services have been used as a rationale or an objective for these incentive programs and (2) to identify the conservation practices required to meet program standards and establish how they link to various ecosystem services. The results of our analysis are used to assess whether incentive programs in California are encouraging conservation practices capable of supplying targeted ecosystem services and whether funds are being distributed accordingly. We then discuss our findings in relation to the management practices and goals for agricultural conservation programs.

2. Materials and methods

2.1. Study area

Climate change and urban sprawl pose significant threats to California agricultural land and food security. Climate change has already impacted California with rising temperatures and shifting precipitation patterns (CNRA, 2009), and these trends are expected to continue over the next century along with more frequent and intense drought, floods, wildfires, and excessive heat events (Pathak et al., 2018; Wong, 2021). The 2014 Sustainable Groundwater Act (SGWA) dictates that California will likely need to idle hundreds of thousands of acres of farmland to meet groundwater sustainability goals by 2040, particularly in San Joaquin Valley (Hanak et al., 2019), and the California Department of Conservation's most recent Farmland Conversion Report states that urban development claimed over 11,000 acres of the state's irrigated farmland between 2014 and 2016 (Newsom et al., 2019). Meanwhile, approximately 96% of California agricultural land is privately owned (Macaulay and Butsic, 2017). Clearly, California farmers face increasingly difficult decisions about land management in today's environmental, political, and economic landscapes.

There are a number of federal and state conservation agriculture programs available to farmers or producers in the State of California. Federal programs date back to the Soil Conservation Act of 1935 which encouraged farmers to use practices that would prevent soil erosion, signed into law by President Franklin Roosevelt in response to the 1930s Dust Bowl. Since then, most of the federal conservation incentives have been written as policy in U.S. farm bills, including the longstanding and still active Conservation Reserve Program (CRP) (established in the 1985 farm bill) and the current flagship program, the Environmental Quality Improvement Program (EQIP) (established in the 1996 farm bill) (Myers, 2023). The state government has also enacted several policies to protect farmland including the

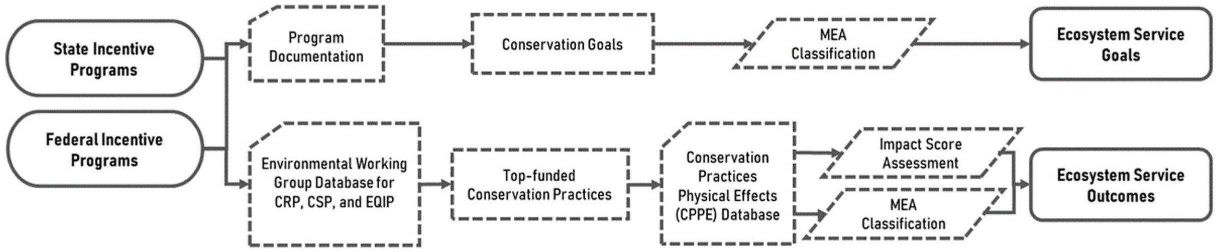


FIGURE 1
The analysis workflow of this study. State and federal incentive programs were analyzed using program documentation to determine their goals, which were categorized into ecosystem service classes using literature review. Federal incentive programs were analyzed using data from the Environmental Working Group to determine the practices and impact scores for each ecosystem service.

Williamson Act of 1965, which allows local governments to hold contracts with landowners to prevent conversion of farmland to other uses. More recent policy from the state includes the suite of Climate Smart Agriculture programs which aim to improve and protect California farmland while minimizing climate impacts. The Healthy Soils Program, State Water Efficiency and Enhancement Program, Alternative Manure Management Program, and Sustainable Agricultural Lands Conservation Program all fall under the Climate Smart Agriculture programs (Lewis and Rudnick, 2019).

California is the third-largest state in the United States and includes a range of diverse environments generated by varying topography, soil type, and proximity to the Pacific coast (Chornesky et al., 2015). Annual temperatures range from 9°C to 36°C, with rainfall between 2.5 inches to over 50 inches in some places, and much of California's climate is classified as either Mediterranean or desert. There are 58 counties in California, with a total population of over 39 million people according to the U.S. Census. California accounts for over 13% of the total United States agricultural production value and produces over 400 agricultural commodities including more than two-thirds of the nation's fruits and nuts (U.S. Census Bureau, 2017). California agriculture operates over 69,900 farms and ranches spanning 24.3 million acres and generating $50.1 billion in revenue in 2019 (CDFA, 2020).

2.2. The review

2.2.1. Data sources

A diagram of the full workflow used for this analysis is shown in Figure 1. We made use of the United States Department of Agriculture (USDA) Conservation Programs Home website[1] and the California Department of Conservation Grant Programs website[2] for an initial search of incentive programs. We used Google to search for additional private and public incentive programs that incentivize conservation on agricultural land in California. We used phrases such as "agricultural incentives," "California agriculture incentive programs," "agricultural conservation easements," "conservation agriculture," "farmland ecosystem services," "farmland conservation," "farm easement," and "sustainable agriculture incentives" to direct our search.

The land practices of individual farmers are not shared with the public and data are not available on farm-by-farm conservation practices. However, data are available on a county level and the non-governmental organization Environmental Working Group (EWG) has built a database on agricultural conservation practices following Freedom of Information Act requests (Environmental Working Group, 2022). The EWG database includes federal funding data and specific conservation practices that received the most funding per county, which offers an opportunity to evaluate the types of ecosystem services outcomes that are explicitly being valued through funding. Federal funding per county from 2017 to 2020 was obtained from the EWG Conservation Database for the following programs: the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), and the Conservation Reserve Program (CRP). These are the three most prominent federal programs under the USDA in terms of funding and enrollment, and payments from these programs are directly tied to conservation practices.

The total amount of funding from these programs, and the total agricultural market value of each county in California, is shown in Figure 2. Federal incentive programs managed by the USDA require landowners to follow national Conservation Practice Standards for a conservation project to receive funding. Each practice has a field/technical guide that outlines the goals and technical information to meet requirements. We obtained the top 20 practices funded through the EQIP, CSP, and CRP programs from 2017 to 2020, from the EWG Conservation Database. We used this database rather than the USDA Natural Resource Conservation Service (NRCS) database because NRCS reports payment obligations per fiscal year rather than direct payments.

Documentation for conservation practices was obtained from the NRCS Conservation Practice Standards technical guides.[3] The physical effects of each conservation practice were collected from the Conservation Practices Physical Effects (CPPE) database for California (NRCS, 2020). This database contains the estimated relative

1 https://www.fsa.usda.gov/programs-and-services/conservation-programs/
2 https://www.conservation.ca.gov/dlrp/grant-programs
3 https://www.nrcs.usda.gov/resources/guides-and-instructions/conservation-practice-standards

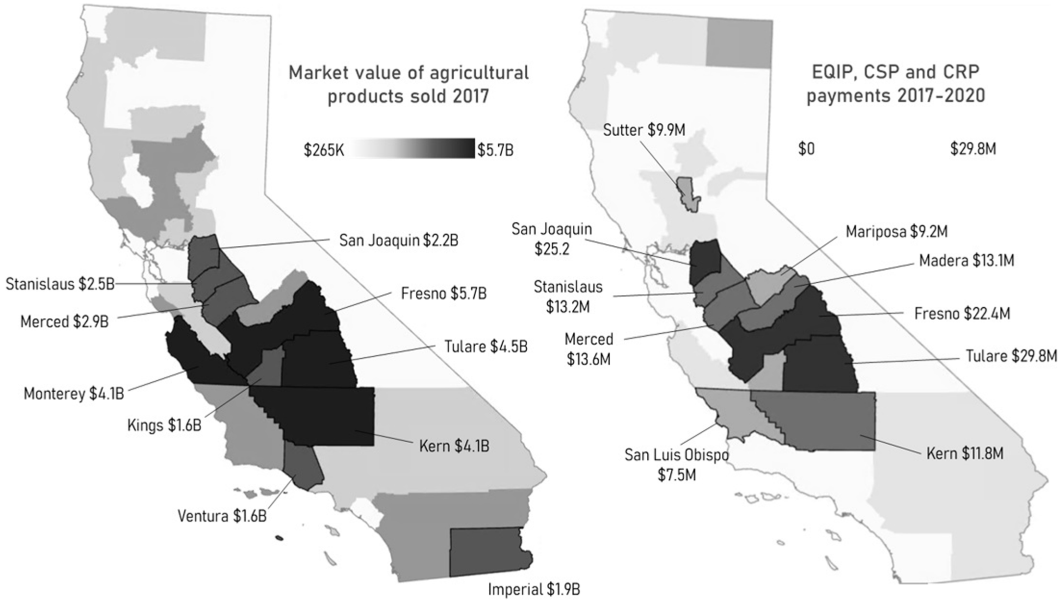


FIGURE 2
Map of the State of California. **(A)** The total earnings from agricultural sales in 2017, per county, in California. Outlined counties are the ten counties that earned the most in sales. **(B)** The total funding received from EQIP, CSP, and CRP, from 2017 to 2020 per county. Outlined counties are the ten counties that received the most from federal programs.

impact of each land practice on 47 ecosystem processes (called "resource concerns" in the CPPE), with impact scores between −5 and + 5. A score of −5 indicates the land practice has a substantial negative effect on the ecosystem process, while a score of +5 indicates the land practice had a substantial improving effect. A score of 0 indicates there is no measurable impact on the ecosystem process.

2.2.2. Identification of programs

We identified a total of 52 incentive programs that are actively being funded, including 28 federal programs, 19 state programs, and 5 private and regional (multiple counties) programs (for the full list see Supplementary Table S1). This study included incentive programs beginning as early as 1965 (the California Land Conservation Act program) up until new programs beginning in 2022 (for example, the Urban, Indoor and Emerging Agriculture (UIE) program). Only programs that incentivize applied practices on farmland or working land in California were included in this study. For example, the USDA's Emergency Watershed Protection Program includes farmers and agricultural landowners as potential beneficiaries, but the program aims to help local communities recover after a natural disaster, and therefore was not included. The Watershed Protection and Flood Prevention Program was included due to the following requirement: "Benefits that are directly related to agriculture, including rural communities, must be at least 20 percent of the total benefits for the project" (NRCS, 2023). Programs that incentivize technology improvements for environmental impact mitigation were only included if they directly improved the land itself. For example, tractor replacement programs were not included because this does not directly impact the improvement or protection of ecosystem services. Both public and private programs were included, though municipal and single-county programs were excluded because they may not influence ecosystem services at a large scale. We accounted for direct incentives including grants, financial assistance, and land acquisition/easements, and indirect incentives including technical assistance, education, and tax abatements/credits.

2.2.3. Characterization of data

Data collected for each incentive program followed the schema implemented by the Extension Foundation in their report on ecosystem services in working lands of the U.S. northeast (Coleman and Machado, 2022), and included the founding date, funding source, managing agency or institution, eligibility requirements, primary incentive mechanisms, and ecosystem services being incentivized. While the northeast assessment used the ecosystem services framework developed by the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), we used the Leemans and De Groot (2003), because it is well-established, clearly defined, and incorporates the full complexity of interactions between ecosystems and people (Flood et al., 2020). We assigned ecosystem services by matching the stated goals of each program with descriptions of services from the MA framework. Most programs incentivize more than one ecosystem function or service, so as many as eight services were assigned to each program. Note that biodiversity is not classified as an ecosystem service within the MA framework, but it has a predominantly positive relationship with ecosystem services and is listed in other classifications such as the Economics of Ecosystems and Biodiversity (TEEB) initiative (TEEB, 2011; Harrison et al., 2014). For the purposes of this study, we counted all references to "biodiversity," "habitat" and "wildlife" preservation in program goals as biodiversity and categorized it as a supporting service.

We assigned different categories based on what is listed on the program webpage and documentation. For example, the California Department of Conservation solicitation notice for the Working Lands and Riparian Corridors program states that program priorities include restoring habitat for native species and wildlife, improving climate resilience through carbon sequestration, enhancing natural water retention, and recharging groundwater supplies. We therefore assigned biodiversity, climate regulation, water regulation, and freshwater provisioning ecosystem services. The program also stipulates that agricultural production should not be hampered by conservation efforts, so the program was assigned food and fiber provisioning as a service as well. For any program that only sought to protect agricultural land from conversion to non-agricultural uses, we assigned food and fiber only. Many programs listed "soil health" as a priority, which is defined by the NRCS as soil's ability to regulate water, sustain plant and animal life, filter pollutants, cycle nutrients, and reduce erosion (USDA, 2015). Therefore, soil health was categorized as water regulation, food and fiber provisioning, water purification, nutrient cycling, erosion regulation, or soil formation depending on the context.

2.3. Analysis

2.3.1. Ecosystem services as an objective for incentive programs

To measure the extent to which various ecosystem services were used as an objective for incentive programs, we listed the ecosystem services prioritized in each program based on stated goals and desired outcomes of the program and by linking conservation goals with ecosystem services according to published scientific articles. We then counted the number of federal and state programs that prioritized each ecosystem service. We categorized results into federal and state programs, and four broad categories defined by the Leemans and De Groot (2003).

2.3.2. Conservation practices

Identifying the conservation practices required for all 52 programs was beyond the scope of this study. Instead, we identified the 20 practices that received the highest payments from the Environmental Quality Improvement Program (EQIP) and the Conservation Stewardship Program (CSP), which paid California landowners roughly \$320 million and \$18 million, respectively, between 2017 and 2020 (Environmental Working Group, 2022). EQIP and the CSP were the top-funded federal conservation incentive programs during the time of our analysis. Each conservation practice designated by NRCS federal programs has received an impact score on specific ecosystem processes based on field analysis in each state, listed in the Conservation Practice Physical Effects (CPPE) database. We used a literature review to match the ecosystem processes that were impacted to ecosystem services. For example, the conservation practice "Forest Stand Improvement," which is "the manipulation of species composition, structure, or density of a stand of trees to achieve desired forest condition" is documented in the CPPE as generating improvements in soil erosion control, soil quality, sediment transport, and soil moisture. These improvements were linked to freshwater provision, food and fiber provision, water purification, water regulation, and biodiversity, according to multiple literature sources (Adhikari and Hartemink, 2016; IPBES, 2019; Steinhoff-Knopp et al., 2021). Conservation practices that did not directly improve or protect nature's ability to supply ecosystem services were categorized as not benefitting ecosystem services. This includes the practices that had negative impacts on ecosystem processes according to the CPPE database.

We summed the CPPE scores (from −5 to +5) for each ecosystem service to estimate the total impact for land practices on ecosystem services. For example, the Forest Stand Improvement conservation practice results in improvements to 34 ecosystem processes that we matched to a total of 17 ecosystem services, with many ecosystem services being matched to several of the processes. Freshwater provision, for example, is impacted by improvements to 26 ecosystem processes, with a total impact score of 34 by the Forest Stand Improvement practice. We compared the ecosystem service contribution (the total impact score) from the top funded practices to the funding received from EQIP from 2017 to 2020 in California. We also summed the CPPE scores for each conservation practice to estimate the total impact of each practice on ecosystem functioning on agricultural land. As an additional assessment of land, we combined the incentive payments from EQIP, CSP, and CRP to find the total payment per county from 2017 to 2020 and compared this payment to the area of agricultural land for each county.

3. Results

Results of this study shows that the provision of food and fiber and the protection or enhancement of biodiversity are the two most prioritized goals of incentive programs for agricultural conservation in California. Figure 3 shows the number of federal and state programs that list various ecosystem services as priorities. Twenty-one federal programs (75% of federal programs) and 16 state programs (84% of state programs) list food production as a goal, and 23 federal (82%) and 9 (47%) state programs list natural or wildlife habitat conservation as a goal. Water regulation, erosion regulation, and climate regulation are also frequently stated priorities in federal and state programs, with 26 total programs (50%) supporting water regulation goals, 19 programs (37%) supporting erosion regulation, and 17 programs (33%) supporting climate regulation goals. Fifteen federal programs and 11 state programs listed soil erosion control or soil formation as a priority. Water cycling and recreation and ecotourism were the least prioritized services, each mentioned one time. Ecosystem services from the MA classification that were not mentioned in any program documentation include genetic resources, ornamental resources, cultural diversity, spiritual and religious values, social relations, photosynthesis an primary production. However, it is likely that many of these services implicitly motivate many conservation programs.

Figure 4 shows the relative impact scores of each of the top-funded federal conservation practices, and the ecosystem services that are impacted. The size of the bar for each practice and service indicates the level of impact. The conservation practice with the highest total impact score was Forest Stand Improvement (impact score of 235), which enhances ecosystem processes that are primarily linked to food provision, freshwater provision, biodiversity, and nutrient cycling. Brush Management, or the removal of woody plants, had the next highest impact score (217), followed by Irrigation Water Management (controlling the volume and flow of irrigated water; 157) and Woody Residue Treatment (the burning, cutting, or removal of residual woody material; 149). These practices benefited provision of food and freshwater, nutrient cycling, water purification, and water regulation, among others. The conservation practices with the lowest total impact

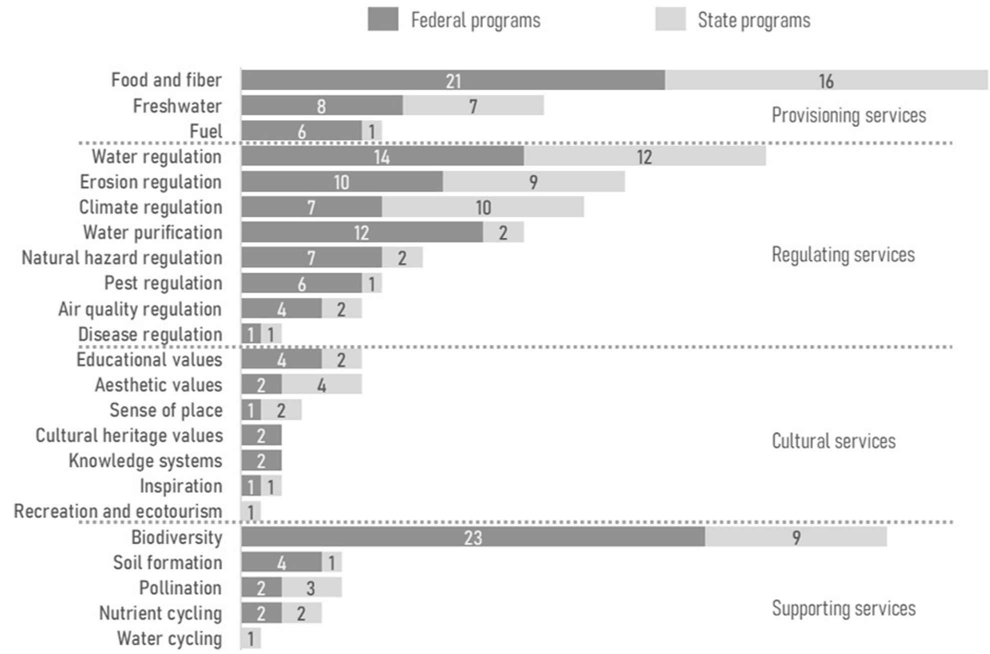


FIGURE 3
The ecosystem services that are incentivized by federal and state programs according to documented program goals. The number indicates the number of programs that included each ecosystem service as a priority.

score of 0 were Combustion System Management and High Tunnel System. Combustion System Management involves the replacement of diesel-powered farm equipment with gas-powered, ethanol-powered, or non-combustion options, resulting in reduced emissions of nitrogen oxides (NOx) and particulate matter (PM). This practice was not considered to be contributing to any ecosystem service since it does not improve or protect an ecosystem's natural ability to regulate air quality or climate naturally; in short, it reduces the demand for ecosystem services but does not enhance the supply. Also, the High Tunnel System practice, or the construction of a tunnel-shaped structure to protect plants and soil from harsh weather conditions, had a net score of 0 due to its negative impact on erosion regulation, freshwater provision, biodiversity, and water regulation, with only minor positive impacts on some regulating and cultural services. The Livestock Pipeline practice (the installation of a structure to convey water for livestock) had the next lowest impact score (4) towards biodiversity and food production, and no direct impact on any other ecosystem service.

The ecosystem services that benefited most from the top 20 funded conservation practices (based on the total impact score across all practices) were freshwater provision, food and fiber provision, and biodiversity, with total impact scores of 345, 292, and 266, respectively. Pest regulation received the lowest total impact with a score of 20, and cultural heritage, sense of place, and genetic resources each received a score of 22. Soil erosion prevention and soil formation, though listed as priorities in many state and federal programs, received moderate benefits with a total impact score of 75. Climate regulation had an impact score of 27.

The funding for each of the top-funded federal conservation practices are shown in Figure 5. The 20 highest-paid practices from EQIP and CSP during 2017–2020 in California received a total of about $279 M (Table 1, for more details see Supplementary Table S2). The largest recipient by far was Combustion System Improvement ($80 M) (Figure 4). The next top-earning conservation practice was Irrigation System-Microirrigation ($59 M), which involves the installation or use of drip irrigation systems to maximize water use efficiency and promote water retention (NRCS, 2020). This practice is primarily beneficial to freshwater provision, biodiversity, and food provision, with only minor improvements to 22 other services. Combustion System Improvement and Irrigation System-Microirrigation together received roughly 50% of the total payments for the 2017–2020 time period, and the remaining 18 practices received the other 50%, less than $20 million each from 2017 to 2020. The lowest paid conservation practice was Subsurface Drain ($2.4 M) followed by Wetland Wildlife Habitat Management ($2.5 M). The Subsurface Drain practice is the installation of an underground conduit to manage soil water, and the Wetland Wildlife Habitat Management practice is the retention or restoration of wetland habitat. Forest Stand Improvement and Brush Management, the practices that provided the largest benefits to ecosystem services, received $16 M and $5 M, respectively.

Eighteen of the top conservation practices, receiving a total of 59% of the federal funding in California, contributed improvements to three ecosystem processes that only benefit livestock (Feed and Forage Imbalance, Inadequate Livestock Shelter, and Inadequate Livestock Water Quantity) and that were not linked to any ecosystem services. The Waste Storage Facility practice, which is the construction of a container to store manure and agricultural wastewater, is not considered in the CPPE to be beneficial to livestock, although it is directly related. This practice received over $14 million and is documented by the USDA to have a worsening impact on emissions of greenhouse gasses, ozone precursors, particulate matter, and airborne reactive nitrogen (NRCS, 2020). This is particularly impactful in California, where areas

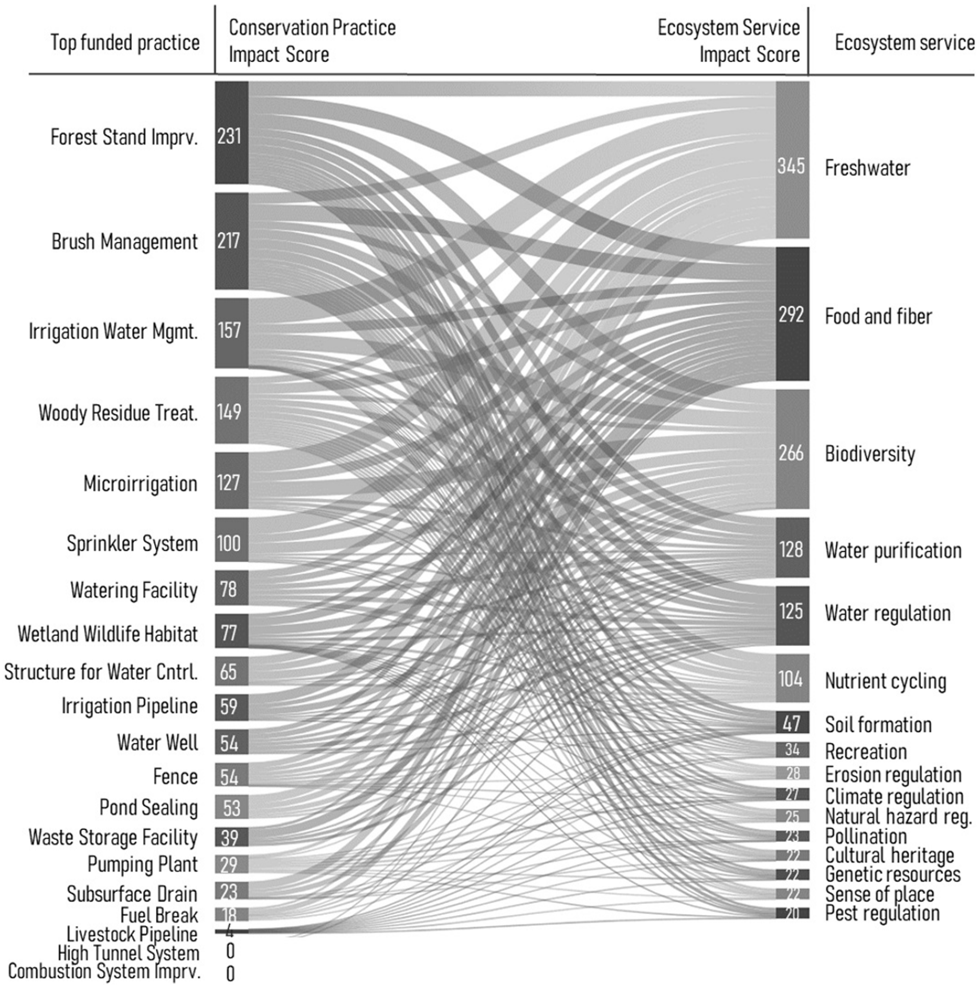


FIGURE 4
The top-funded conservation practices from CSP and EQIP (left) and their impact on ecosystem services (right). The impact score and size of the bar for each conservation practice reflects the impact of that practice on all possible ecosystem services combined. The impact score and size of the bar for each ecosystem service reflects the total impact from all the top-funded conservation practices.

with the most productive agriculture (e.g., the Central Valley) are also those with the worst air quality in the country (Schiffman, 2021).

The 2017–2020 EQIP, CSP and CRP funding is plotted against the agricultural acres for each county in Figure 6A, and point size is larger for counties with higher agricultural earnings. From 2017 to 2020, Tulare County received $29.8 M from EQIP, CSP and CRP combined, more money than any other county. The next top-paid county was San Joaquin County ($25.2 M), followed by Fresno ($22.4 M) and Merced ($13.5 M). The lowest paid county for that time span was Orange County ($0). The payment data provided by the USDA only includes conservation practices that had more than five contracts in each county, therefore Orange County may have received some funding but it was unlisted due to the low number of contracts. The next lowest paid county was Santa Clara County (about $1,400), followed by Napa County ($31,000) and Del Norte County ($43,000). Payments from EQIP, CSP and CRP increase fairly linearly with the area of farmland per county ($R^2 = 0.468$), but there are some outliers (Figure 6A). Kern County received $12.3 M and has 2.3 million acres of farmland, while Fresno County received $22.3 and has 1.6 million acres of farmland. Monterey and Tulare Counties have similar acreage of farmland (1.3 M acres and 1.25 M acres, respectively) and agricultural market value ($4.1B and $4.4B), but Monterey received less than one quarter ($5.8 M) of Tulare's $29.8 M. San Joaquin and Stanislaus counties also have similar farmland acreage and agricultural market value, but San Joaquin received $25.2 M in federal conservation incentive funding and Stanislaus received $13.2 M.

In Figure 6B, the top agricultural commodities sold in 2020 from each of the ten highest-paid counties are listed in order of payments earned from EQIP, CSP and CRP. Tulare and Merced Counties' top commodity in 2020 was cow milk, and almost all the remaining counties earned the most from the production of fruits and tree nuts, except for Mariposa County. San Luis Obispo and Sutter are the only counties that did not earn significant income from the production of animal products, and six of the ten counties earned significant income from the sale of vegetables.

4. Discussion

Competing demands for increased food production, climate resilience, and environmental sustainability make it necessary for the

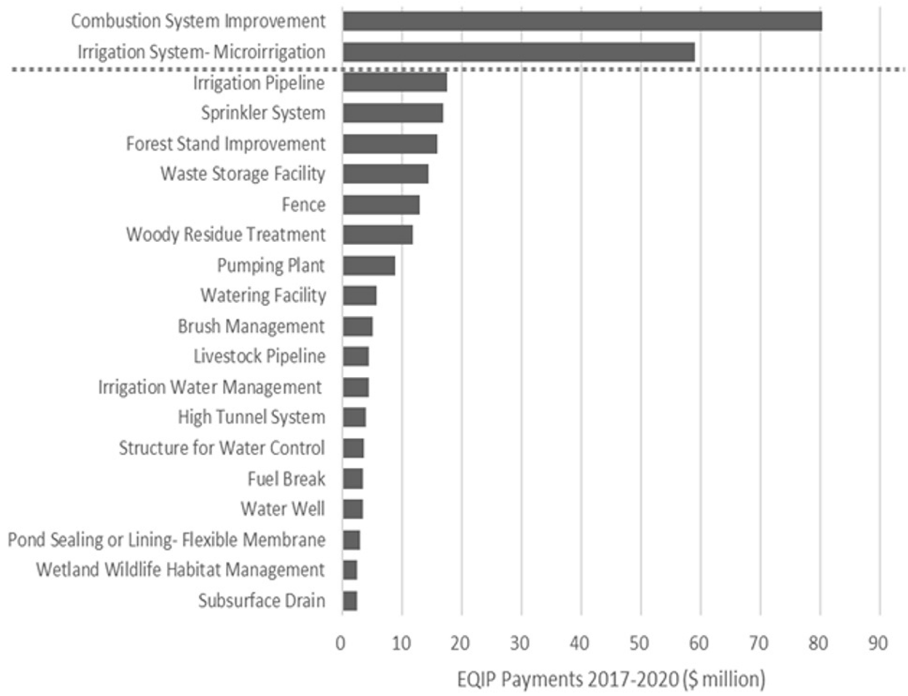


FIGURE 5
Payments for the top-funded conservation practices from EQIP and CSP from 2017 to 2020. The dotted line marks 50%, i.e., 50% of the total funding went to practices above the line, and 50% went to the practices below the line.

U.S. to adopt a different agricultural model that can accomplish all these goals. Regenerative agriculture, multifunctional agriculture, and other models have been put forward as options that can help meet these demands if resources are allocated intelligently and if ecosystem services are incorporated in decision making (Kremen et al., 2012; Martin and Isaac, 2018). Current agricultural conservation incentive programs associated with regenerative agriculture aim to support the maintenance or improvement of a variety of provisioning, regulating, cultural, and supporting ecosystem services in California. However, this study finds that the ecosystem service impacts of federal programs, although important, are not necessarily aligned with the goals of the State of California. Below we discuss the extent to which these programs align with various objectives or are missing the mark and discuss them in relation to management and suggestions for future work.

4.1. Ecosystem services and conservation practices

Our first objective for this study was to understand the extent to which various ecosystem services were prioritized in agricultural conservation programs in California. We found that federal programs list biodiversity, food production, soil quality (including both soil formation and erosion control), and water regulation as clear priorities (Figure 3). This largely aligns with the State program goals which included both biodiversity and food and fiber as the most frequently listed priorities. Biodiversity, (especially organisms related to pollination and soil quality) is important for crop production in California and around the world (Klein et al., 2012). The priority for food and fiber production is not surprising given California's large contribution to food production in the U.S. and the focus of this study on agricultural lands (U.S. Census Bureau, 2017). Soil erosion prevention has long been identified as important in land degradation particularly in agricultural land and it contributes to significant loss of soil and soil fertility (Willemen et al., 2018; Smetanová et al., 2019). Water regulation, another of the top priority services for state and federal programs, is also vital for food production especially where there is irrigated agriculture in water-scarce places (Engelbert and Scheuring, 2022). California is a water-scarce state with 10 of the last 14 years experiencing drought (Mann and Gleick, 2015). The importance of water for agricultural production and industry cannot be overstated.

Unlike federal programs, California State programs listed climate regulation as a top priority, and there are many non-agricultural programs dedicated entirely to climate change mitigation in California. This precedence is likely due to the increased frequency and intensity of climate-related disasters such as wildfire, drought and floods in the state (Goss et al., 2020; Javadinejad et al., 2021), as well as California's long history as a leader in subnational climate change policy (Mazmanian et al., 2020). Cultural services were the least frequently prioritized category despite evidence showing that human dependence on cultural services increases following economic development, even while dependence on provisioning and regulating services decreases (Guo et al., 2010). Although cultural services such as aesthetic value, recreational activities and tourism do not increase productivity in agricultural landscapes, agritourism activities such as vineyard tours do provide substantial income. California's vineyards are estimated to generate over 25 million tourist visits and $8.56 billion in tourism expenditures each year, benefitting both vineyard

TABLE 1 Twenty highest-paid conservation land management practices funded by the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) from 2017 to 2020 in California, listed in order of funding.

Land practice	Funding	Description	Ecosystem services
Combustion system improvement	$80,438,008	Replace, repower, or retrofit an agricultural combustion system and related components or devices.	None
Irrigation system-microirrigation	$59,132,833	An irrigation system for frequent application of small quantities of water on or below the soil surface as drops, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, and biodiversity
Irrigation pipeline	$17,472,382	A pipeline and appurtenances installed to convey water for storage or application as part of an irrigation water system.	Freshwater, food and fiber, water purification, water regulation, nutrient cycling, and biodiversity
Sprinkler system	$16,797,571	A distribution system that applies water by means of nozzles operated under pressure	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, and biodiversity
Forest stand improvement	$15,963,891	The manipulation of tree and shrub species composition, structure, or density to achieve desired forest conditions.	Food and fiber, raw materials, genetic resources, freshwater, climate regulation, water regulation, erosion regulation, natural hazard regulation, pollination, pest regulation, water purification, recreation, sense of place, cultural heritage, soil formation, nutrient cycling, and biodiversity
Waste storage facility	$14,403,080	An agricultural waste storage impoundment or containment made by constructing an embankment, excavating a pit or dugout, or by fabricating a structure.	Freshwater, biodiversity, and food and fiber
Fence	$12,876,919	A constructed barrier to animals or people.	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, biodiversity, climate regulation, erosion regulation, natural hazard regulation, and pest regulation
Woody residue treatment	$11,809,686	The treatment of residual woody material that is created due to management activities or natural disturbances.	Food and fiber, raw materials, genetic resources, freshwater, climate regulation, water regulation, erosion regulation, natural hazard regulation, pollination, pest regulation, water purification, recreation, sense of place, cultural heritage, soil formation, nutrient cycling, and biodiversity
Pumping plant	$8,853,811	A facility that delivers water or wastewater at a designed pressure and flow rate.	Food and fiber, water regulation, water purification, freshwater, biodiversity, and soil formation
Watering facility	$5,677,113	A watering facility stores or provides drinking water to livestock or wildlife	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, and biodiversity
Brush management	$5,000,013	The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious.	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, biodiversity, climate regulation, genetic resources, erosion regulation, natural hazard regulation, pollination, pest regulation, and sense of place
Livestock pipeline	$4,469,634	A pipeline and appurtenances installed to convey water for livestock or wildlife.	Food and fiber, and biodiversity
Irrigation water management	$4,465,962	The process of determining and controlling the volume, frequency, and application rate of irrigation water.	Food and fiber, raw materials, genetic resources, freshwater, climate regulation, water regulation, erosion regulation, natural hazard regulation, pollination, pest regulation, water purification, recreation, sense of place, cultural heritage, soil formation, nutrient cycling, and biodiversity
High tunnel system	$3,906,860	An enclosed polyethylene, polycarbonate, plastic, or fabric covered structure that is used to cover and protect crops from sun, wind, excessive rainfall, or cold, to extend the growing season in an environmentally safe manner.	Food and fiber, raw materials, genetic resources, freshwater, climate regulation, water regulation, erosion regulation, natural hazard regulation, pollination, pest regulation, water purification, recreation, sense of place, cultural heritage, soil formation, nutrient cycling, and biodiversity

(Continued)

TABLE 1 (Continued)

Land practice	Funding	Description	Ecosystem services
Structure for water control	$3,586,212	A structure in a water management system that conveys water, controls the direction or rate of flow, maintains a desired water surface elevation, or measures water.	Food and fiber, freshwater provision, biodiversity, nutrient cycling, natural hazard regulation, water purification, and water regulation
Fuel break	$3,360,784	A strip or appropriately sized block of land on which the vegetation, debris, and litter have been reduced and/or modified to control or diminish the spread of fire.	Food and fiber, freshwater, climate regulation, water regulation, water purification, nutrient cycling, erosion regulation, natural hazard regulation, soil formation, biodiversity, pollination, pest regulation, recreation, sense of place, and cultural heritage
Water well	$3,341,494	A hole drilled, dug, driven, bored, jetted, or otherwise constructed into an aquifer for agricultural water supply.	Freshwater, food and fiber, water purification, water regulation, soil formation, nutrient cycling, and biodiversity
Pond sealing or lining- flexible membrane	$2,921,831	A liner for an impoundment constructed using a geomembrane or a geosynthetic clay material.	Food and fiber, water regulation, water purification, freshwater, and biodiversity
Wetland wildlife habitat management	$2,497,693	Retaining, developing or managing wetland habitat for wetland wildlife.	Food and fiber, raw materials, genetic resources, freshwater, climate regulation, water regulation, erosion regulation, natural hazard regulation, pollination, pest regulation, water purification, recreation, sense of place, cultural heritage, soil formation, nutrient cycling, and biodiversity
Subsurface drain	$2,385,325	A conduit, or system of conduits, installed beneath the ground surface to manage soil water conditions.	Freshwater, food and fiber, water purification, water regulation, nutrient cycling, and biodiversity

The ecosystem services column indicates the services that are impacted, positively or negatively, by the practice.

owners and surrounding local economies (WineAmerica, 2022). While tourism provides direct returns for farmers, other cultural services such as aesthetic value and educational values are positive externalities that benefit surrounding communities and require financial support.

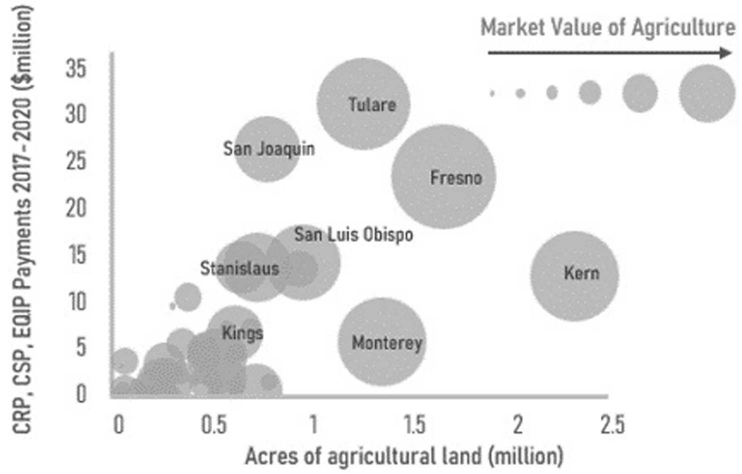
Our second objective was to identify the conservation practices required to meet program standards, and to assess whether those practices aligned with the goals in terms of ecosystem services. Unfortunately, we found that the two highest paid practices, Combustion System Improvement and Microirrigation ($139 M combined), contributed zero- to moderate benefits to ecosystem services, while the practices that generated the greatest positive impact for ecosystems, Forest Stand Improvement and Brush Management, were underfunded. Food and fiber provision, biodiversity, and freshwater provision all had high impact scores from conservation practices. State governments are responsible for assigning the payment value per acre for federal conservation practices, so we can assume the payments reflect the state's values, and yet we found that federal conservation practices focused very little on climate regulation, soil quality (including formation and erosion control), pest and hazard regulation, or any of the cultural services (Figure 3). Therefore, the goals of federal and state programs, which included climate regulation, water purification, erosion regulation, pollination and air quality regulation, are not aligned with the means of execution via the top-funded federal conservation practices.

A limitation of this analysis is the interpretation of conservation practices in isolation, an explicit limitation of the impact scores provided in the CPPE (NRCS, 2020). A group or system of practices is likely to have a greater potential for ecosystem service improvement, and some practices are considered "facilitating practices" such that they can only be assessed when used in conjunction with other practices. For example, the Fence practice (a constructed barrier to animals or people, Table 1) is a facilitating practice, and would therefore likely have a greater impact on ecosystem services if analyzed in conjunction with other practices such as prescribed grazing or tree/shrub establishment.

Although some well-funded conservation practices produce ecosystem services, there are trade-offs that exist and conflicts with other California legislation or program goals. For example, the Water Well conservation practice received over $3 million for the drilling of a well to pump water from an aquifer, which promotes irrigation and food production but depletes valuable groundwater resources and goes against the goals of the Sustainable Groundwater Management Act. Additionally, the Waste Storage Facility practice increases greenhouse gas emissions and harmful pollutants (NRCS, 2020). Payments from this highly-funded federal program are being misdirected to polluting operations while many farmers are denied contracts with EQIP that might help them to provide measurable improvements to ecosystem services, to the benefit of farms and rural communities at large (Happ, 2022). This reflects previous work that finds that tradeoffs between ecosystem services, particularly on working lands, often come at the expense of regulating, cultural and supporting services, to benefit agricultural production of food and materials (Final Report – The Economics of Biodiversity, 2021).

Until the 2018 Farm Bill, 60% of all EQIP funding was dedicated to livestock producers, and this target was only minorly reduced to 50% for fiscal years 2019 through 2023, while wildlife practices accounted for only 7.6% of EQIP funds through wildlife conservation practices and initiatives (USDA, 2020). Tulare and Fresno, the two highest-paid counties from EQIP, CSP and CRP, are two of California's top dairy-producing counties (CDFA, 2020). Kern County, which has more land in agriculture compared to Tulare and Fresno but received less money from EQIP, is

A



B

County	Top Commodities
Tulare	cow milk, fruits/tree nuts, cattle/calves, poultry/eggs, grains
San Joaquin	fruits/tree nuts, cow milk, vegetables, nursery, cattle/calves, poultry/eggs
Fresno	fruits/tree nuts, vegetables, poultry/eggs, cattle/calves, cow milk
Merced	cow milk, fruits/tree nuts, poultry/eggs, vegetables, cattle/calves
Stanislaus	fruits/tree nuts, cow milk, poultry/eggs, nursery, cattle/calves
Madera	fruits/tree nuts, cow milk, cattle/calves, vegetables
San Luis Obispo	fruits/tree nuts, vegetables, nursery
Kern	fruits/tree nuts, vegetables, cow milk, cattle/calves, nursery
Sutter	fruits/tree nuts, vegetables, grains, nursery
Mariposa	cattle/calves, fruits/tree nuts

FIGURE 6
(A) The combined funding from EQIP, CSP, and CRP payments from 2017 to 2020 compared to the acres of cropland per county. Circle size increases with agricultural market value from 2020. **(B)** Top grossing commodities for the top ten highest paid counties from EQIP, CSP and CRP. Counties are listed in order of payments received by federal programs.

predominantly a "specialty crop"-producing county, growing mostly fruits, vegetables, and nuts such as grapes, carrots, citrus, almonds and pistachios (Fankhauser, 2020). It seems reasonable to conclude that conservation funding from the top federal programs is aligned with agricultural income and product type rather than with environmental needs. This, along with the results of this study showing the number of federal conservation practices that benefit livestock operations and have little positive impact on ecosystem services, confirms testimony from prominent leaders in the regenerative agriculture movement (COA, 2022) and research done by the USDA itself (Hansen and Hellerstein, 2006) stating that much of the funding from CSP and EQIP is being used to support livestock operations, which when done intensively can be extremely damaging to the environment, the global climate, human health, and animal welfare (Burkholder et al., 2007; Emel and Hawkins, 2010; Pluhar, 2010). While there is a considerable amount of rangeland in California used for livestock production, and rangeland has been established as a generator of ecosystem services, there are currently over one thousand Concentrated Animal Feeding Operations (CAFOs) actively operating in California (Johnsen et al., 2015). Prior to the 2002 Farm Bill, CAFOs were explicitly excluded from EQIP funding (Gurian-Sherman, 2008); it may be of benefit to renew this restriction in future Farm Bills.

The ecosystem services framework has enormous potential for influencing conservation of biodiversity and ecological function while also providing multiple socioeconomic benefits to rural communities, particularly in agroecosystems. Explicit incorporation of ecosystem services in conservation incentive programs may help to align the goals and results of these state and federal programs. Soil health and climate regulation in particular require more dedicated and targeted funding in California, and conservation practices that predominantly benefit environmentally damaging operations such as large-scale meat and dairy farming operations should be excluded as beneficiaries from these incentive programs.

4.2. Monitoring and data transparency

Continual monitoring and oversight are critical to the success of conservation efforts, but due to the complexity of landowner-program relationships, the varied and fragmented nature of agricultural ecosystems, and the limitation of spatial data, quantifiable measurement of success is challenging (Smith and Weinburg, 2014). The Conservation Effects Assessment Project (CEAP) is a multiagency effort to report on the results of conservation practices funded by NRCS, but CEAP relies heavily on farmer survey data and sampled natural resource data to estimate nationwide success of conservation programs (USDA, 2022). The USDA's Agricultural Research Service also monitors sustainable agriculture projects through the Long-Term Agroecosystem Research Network, which includes 18 sites across the country developed to research the sustainable intensification of agroecosystems while minimizing or reversing negative impacts on the environment (Bean et al., 2021). These long-term research sites are limited in their ability to estimate impacts of conservation practices being used on millions of acres of crop and grazing and land. In fact, there is no site in California.

Further, there can be little analysis of conservation programs by parties outside the USDA due to the highly restrictive nature of spatial data sharing as a result of the 2008 Farm Bill (Rissman et al., 2017). Since the passing of the bill, public access to parcel-level data about agricultural lands enrolled in conservation programs through the USDA is legally prohibited due to privacy concerns of landowners; this data is only available to the USDA and other partnering federal agencies. Public access is limited to county-level data, which, particularly for large states like California, is too coarse for definitive monitoring. Conservation easements, which are separate from the conservation practices applied through the USDA, have been mapped on a parcel-level, but the National Conservation Easement Database is incomplete (and sometimes inaccurate) due to data capacity limitations and organizational reluctance to contribute information (Rissman et al., 2017). Resources available through state governments may be more reliable, however, such as the California Conservation Easement Database funded by the California Natural Resources Agency and the California Department of Water Resources.

With access to spatial boundaries of easements, remote sensing may be a powerful tool for monitoring conservation success. For example, the Nature Conservancy developed an interactive web tool that uses satellite remote sensing data to monitor compliance on grazed conservation lands, with highly impactful results (Ford et al., 2017). Remote sensing data ranges from free, public-access, moderate-resolution data with widely-researched methods for analysis (for example, the Landsat series) to expensive, commercial data at very high resolutions capable of counting individual animal species on the ground (for example, Maxar's Earth observation satellites). Drone imagery and airborne sensors have been used for precision agriculture but are currently underutilized in conservation monitoring (Nagendra et al., 2013). The ecosystem services framework is inherently coupled with remote sensing technology since the mapping of ecosystem services relies on modeling and data proxies often derived from imagery. Ecosystem services mapping has the potential to highlight the services delivered by various conservation practices and the shifts that will occur due to climate change or land use change (Balvanera et al., 2001).

4.3. Conclusion

Making the transition to a multifunctional, regenerative, or ecological agriculture is a process that requires funding, training, new knowledge, and collaboration between researchers, policymakers, and rural communities (Carlisle et al., 2019; Hammelman et al., 2020). The ecosystem services framework is a powerful tool for evaluating tradeoffs between the delivery of services such as food production, wildlife habitat and carbon sequestration, and "disservices" such as water degradation and soil erosion. Developed to account for and value the services provided by nature for human well-being, ecosystem services framework, classifications and models can provide a basis for assessing successes in incentive payments to farmers in exchange for delivering services (Reed et al., 2014). Understanding the gaps between program objectives and conservation needs, particularly where billions of tax-payer dollars are being spent to achieve specific ecological outcomes on privately-owned working land, is timely and necessary. The need for alternative agricultural models that focus on environmental sustainability, community engagement, and food security is gaining interest in rural communities, in scientific research and on the political front (COA, 2022). Incentives can encourage private landowners to work towards our nation's most critical conservation goals (Bean et al., 2003) but if incentive programs are to be successful, careful assessment of the true value of ecosystem services must be done. State legislators responsible for incentive programs in California realize the need for climate resilience, protection of natural resources, and the continued success of food production. However, there is a gap between the goals of the State and those that are realized by federal funding for conservation practices. Even more worrisome is that the top funded federal practices are not necessarily the ones that deliver the best benefits for conservation of the environment.

The monetary compensation for California's prioritized ecosystem services should be sufficient to compete with other forces that may persuade a landowner to convert their agricultural land for non-agricultural purposes, or to use agricultural methods that leave the land permanently degraded. Adoption of practices that improve ecosystem services at scale and with support from federal and state institutions can increase agricultural profitability and sustainability, while positioning working lands as multifunctional ecosystems (Coleman and Machado, 2022). Conservation practices that promote intensive meat and dairy farming may be re-evaluated to determine whether these practices are receiving unfair funding compared to practices that promote ecosystem services. Federal and state funding for conservation practices should be allocated based on true conservation and ecosystem needs on agricultural land, with input from scientists, landowners, and community members. The ecosystem services framework is an excellent tool for identifying needs and impacts in conservation planning, and the methods used in this study may be applied in other states to distinguish between the goals of incentive programs and the ecosystem service impacts from the top-funded federal practices.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

JL and BNE contributed to the conception of the research question and the design of the study. JL organized the data, performed the analysis, and wrote the drafts of the manuscript. BNE gave inputs on analysis and edited manuscript drafts. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1239015/full#supplementary-material

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