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Cropland repurposing as a tool for water sustainability and just land transition in California: review and best practices

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There is not enough water in California to support current water uses and preserve healthy environments. California aquifers have been chronically depleted over decades, causing household water insecurity, degrading groundwater-dependent ecosystems, affecting small and medium farmers, and inducing subsidence. The California government enacted the Sustainable Groundwater Management Act more than a decade ago to prevent declining aquifer levels to continue causing undesirable results, which has driven the necessity to reduce irrigated agriculture by about half million hectares. If this change is left to market forces alone, cropland retirement could disrupt local economies and vulnerable communities, increasing the levels of injustice for local residents and threatening farmer and farmworker livelihoods. However, when cropland repurposing is strategically organized and managed in collaboration among all the involved groups, it can enhance quality of life in agricultural disadvantaged communities, diversify regional economies, generate local socioeconomic opportunities, and improve environmental health while simultaneously fostering food and nutrition security and advancing water sustainability. In this study, we present a systems-level, coproduced Framework of best practices in cropland repurposing to achieve socioenvironmental and economic benefits for all. The Framework is informed and supported by peer-reviewed science, authors' first-hand experiences, and public engagement about the topic for several years. Our team includes scientists, community leaders, and other experts in cropland repurposing, socioenvironmental justice, agriculture, climate change, land trusts, disadvantaged communities, energy, nonprofit work, Indigenous knowledge, and ecosystems. The Framework includes guiding objectives, best practices, and implementation strategies to overcome co-occurring challenges. We conduct an extensive literature review of the current status quo to support the best practices identified in our Framework. This review and coproduced Framework aim to provide best practices for developing new solutions without causing new problems, while fully considering the impacts on all groups affected firsthand by cropland repurposing.

KEYWORDS

sustainable agriculture, water management, environmental justice, circular economy, land use transition, food and nutritional security, climate resilience, multibenefit land repurposing

1 Introduction: water, socioenvironmental justice, and cropland repurposing in California

California is experiencing a water crisis that has compromised cropland use over the last decades. From pre-Gold Rush era issues to current overallocation of water resources and climate change, California faces many historical, structural, and environmental challenges. These challenges have disproportionately affected health, justice, and socioeconomic development for rural disadvantaged communities, Tribes, and the environment, while creating economic risk and disparities among farmers. California and southwestern North America are also experiencing a multidecade megadrought (Liu et al., 2022). Since 2000, the region has experienced the driest period in the last 1,200 years, with 46% attributed to anthropogenic climate change (Williams et al., 2022). Acute droughts (2012–2016, 2020–2022) led to water restrictions across the state, thousands of dry wells (Pauloo et al., 2020; Rodriguez-Flores et al., 2023), income losses for California agriculture between 2.6% and 5.9%, and losses of up to 3.8% of farmworker and agricultural processing jobs (Howitt et al., 2014; Medellín-Azuara et al., 2022). Climate projections estimate that multiyear droughts similar to those in 2012–2016 and 2020–2022 will be 3–15 times more frequent by the end of the century as heat-trapping emissions rise (McEvoy et al., 2020).

Consequences from chronic groundwater depletion during the acute 2012–2016 drought led the State of California to enact the Sustainable Groundwater Management Act (SGMA, 2014) to protect groundwater resources and achieve groundwater sustainability by mid-century. Agriculture represents 80% of the water use in California (DWR, 2024) and 90% in the San Joaquin Valley (Hanak et al., 2017). Groundwater Sustainability Agencies (GSAs), created to implement SGMA and responsible for groundwater sustainability, are incorporating different strategies locally to manage groundwater demand, such as pumping fees and allocation plans. While these local actions will reduce groundwater demand, they will also reduce irrigated cropland. If the transition away from irrigated cropland is not equitably managed, it can disproportionately affect small and medium-sized farmers, and the residents of agricultural disadvantaged communities. Other external market forces may also negatively affect regional resilience, including foreign investments in cropland by non-farmers, farm consolidation, and unregulated industrial development in agricultural areas.

Strategic cropland repurposing is one tool for managing this transition and can address problems that would otherwise be created by cropland retirement alone, while generating multiple benefits for the groups involved and for society as a whole. This includes new job opportunities and income sources from a green economy, ecosystem resilience, water security, and socioenvironmental justice (EDF, 2021; Espinoza et al., 2023; Fernandez-Bou et al., 2023).

For years, many practitioners have sought a science and practice-based framework to guide cropland repurposing efforts in California at the systems level. Systems level thinking means holistically considering interactions and impacts on various subsystems—social, ecological, economic, and agricultural—across a region. Here we present a systems-level, coproduced Framework of best practices in cropland repurposing to facilitate socioenvironmental and economic benefits for all, and a glossary for key definitions (Table 1). This work is informed by peer-reviewed science, authors' first-hand experiences, and public engagement about the topic for several years. The Framework includes guiding objectives and best practices for overcoming co-occurring challenges, illustrating how different topics are intertwined and interdependent. We conduct a literature review of the current status quo and to support the best practices identified in our Framework. Our audience includes scientists, policymakers, practitioners, and anyone working in this novel field of study and practice. Our motivation for this review and the participatory science-based Framework is to ensure that anyone following these best practices can develop new solutions without causing new problems or exacerbating existing ones, while fully considering the impacts on all groups affected firsthand by cropland repurposing.

2 Status quo and climate change

This section summarizes the environmental, social, and economic challenges, and the legacy of injustice in California's agricultural regions, especially the Central Valley, exacerbated by climate change. These challenges highlight the agricultural sustainability crisis and the urgent need for transformative action, while also presenting opportunities for a just land transition.

2.1 Historical land transitions and current land ownership

California's agricultural landscape has evolved over the past centuries driven by settler expansionist goals, market demands, labor shifts, technological advances, water infrastructure investments, environmental regulations, and climate change. The first major transition was the forced displacement and genocide of Native Americans by settlers (CA Executive Order N-15-19, 2019), dispossessing the original Indigenous Peoples of land and water in favor of Western land ownership and management and commercial agriculture (Almaguer, 2009; Whyte, 2016). By the 1850s and early 1900s, wheat and hay were the main crops, while fruit and nut trees dominate at present (Olmstead and Rhode, 2017). This shift toward high-value crops like nut trees led to unsustainable practices, particularly large monocultures, where reliance on chemical fertilizers, pesticides, and groundwater overpumping have degraded environmental and public health.

Water scarcity prompted the California government to incentivize water-efficient practices such as drip irrigation. However, this measure unintentionally allowed for the expansion of agriculture to marginal lands, particularly for water intensive perennial crops like almonds and pistachios, reducing groundwater recharge from flood irrigation and increasing soil salinity (Ward and Pulido-Velazquez, 2008; Mall and Herman, 2019; Pérez-Blanco et al., 2021). Perennial crops require consistent irrigation, reducing water management flexibility during droughts compared to annual crops that are less water dependent and can be idled during dry years. Nut crops also demand less labor due to mechanization.

The 2012–2016 drought showcased the gravity of these issues, as thousands of wells dried and urban areas enacted water conservation measures. Small and medium farmers were also negatively affected, while larger landowners expanded their holdings (Rempel et al., 2024), and agricultural revenues and perennial crop surface area increased to record levels in 2013 and 2014 (Cooley et al., 2015). However, the COVID-19 pandemic disrupted almond exports, with massive price drops after 2020 (USDA, 2023). In 2023, the land area of bearing almond orchards decreased for the first time since 1995 (Almond Board of California, 2024), and in 2024 some almond-investing corporations in California declared bankruptcy (James, 2024).

Since the 2000s, farmland purchases by limited liability companies (LLCs) have surged, reflecting land ownership consolidation (Rempel et al., 2024). Between 2017 and 2022, thousands of small and mid-size farms disappeared, while farms over 1,000 acres grew in number (USDA, 2024), leading to the displacement of small and tenant farmers. Small-scale farmers in California often grow annual crops for local consumption and lease land with shallower irrigation wells that are the first to dry out when groundwater is overextracted (Rempel et al., 2024). Small farms increase food quality and access, diversification, yields, indirect employment in rural areas, and food sovereignty at local levels (household and individual) (Mayfield, 1996; Ntihinyurwa and de Vries, 2021; Ricciardi et al., 2021). However, socially disadvantaged farmers have not been properly engaged in groundwater sustainability planning, despite being more likely to adopt regenerative practices such as soil health improvement

TABLE 1 Definitions and clarifications.

Cropland repurposing: Multibenefit cropland repurposing is the transition of irrigated conventional agriculture to uses that promote positive side effects, such as water savings, improved public health, new socioeconomic opportunities for local communities, and ecosystem benefits. In some cases, farmers can be compensated to transition their farmland to alternative beneficial uses, such as parks, habitat corridors, new socioeconomic opportunities, non-irrigated rangeland, space for green economy activities and renewable energy, and wildlife-friendly multibenefit recharge basins (EDF, 2021; Fernandez-Bou et al., 2023). To be successful, strategic cropland repurposing should follow a transdisciplinary approach. A transition to agroecology, regenerative, or other sustainable forms of agriculture can be considered cropland repurposing.
Cropland retirement: Removal of land from agricultural production, often due to lack of access to water for irrigation, excessive soil salinity, or to other issues inhibiting farming.
Disadvantaged community: Community classified as disadvantaged by a government tool according to one or more indicators. If the indicator is only the Median Household Income of the community (MHI; as used by the California Department of Water Resources), communities can be spatially identified by their boundaries, and they are classified as disadvantaged (MHI < 80% of the state's) or "severely disadvantaged" (MHI < 60% of the state's). The most common classification in California is given by the CalEnviroScreen score, which is calculated after 21 indicators about pollution burdens and population characteristics. Its census tract scale, while appropriate for cities, limits its use in underserved small rural communities. Some indicators of disadvantage are often opposite between rural and urban areas, which may lead to biases in definitions. The minimum size considered in the classification can also affect very small communities by 'dissolving' them within wealthier areas (De León, 2012; Fernandez-Bou et al., 2021b; OEHHA, 2021).
Socially disadvantaged farmers and ranchers: The United States Department of Agriculture (USDA) defines socially disadvantaged farmers and ranchers (SDFRs) as those belonging to groups that have been subject to racial or ethnic prejudice. SDFRs include farmers who are Black or African American, American Indian or Alaska Native, Hispanic or Latino, and Asian or Pacific Islander. For some but not all USDA programs, the SDFR category also includes women.
Idle land: Land is usually idled when water scarcity does not allow irrigation, leaving the land temporarily without production while access to water is limited. This is common in California and other Mediterranean climate regions in which the wet season is not overlapped with the main plant growing season. Often, to avoid undesirable vegetation or to prevent endangered species from finding suitable habitat in the idle lands, California farmers use tillage in these dry lands, which releases large amounts of pesticide-laden dust and degrades the soil health (University of California, Agriculture and Natural Resources, 1994; Sanz-Pérez et al., 2019). Often, the concept of "idle" is confused with "fallow". Dust from idle land can be reduced by decreasing tillage (Sharratt et al., 2010). Idling land is not cropland repurposing.
Fallowed land: Land is fallowed to bring soil health by allowing the soil to rest, often with beneficial cover crops, even to create habitat for beneficial environmental purposes, and for 5 years or less (García-González et al., 2018; Ghimire et al., 2019; Sanz-Pérez et al., 2019; Tarjuelo et al., 2020; Eurostat, 2024). Fallowing land with adequate practices to improve soil health, as the internationally recognized definitions of fallow land indicate, can decrease dust emissions (Thorne et al., 2003) and even prevent desertification (Ikazaki et al., 2011). Fallowing land is not cropland repurposing.
Transdisciplinarity: Approach to work that involves integrating the knowledge and methods of different scientific disciplines with collaboration with interested groups to create shared knowledge that is meaningful to people affected first-hand. While multidisciplinarity involves scientists working on the same topic with their own approaches, and interdisciplinarity involves scientists blending their approaches to create a new one, transdisciplinarity transcends interdisciplinarity by integrating non-academic groups interested in and affected by the process.
Agrivoltaics: Systems that combine solar photovoltaic electricity generation and agriculture (crops and/or livestock) on the same shared parcel of land. Solar panels can be installed between or above crops, and they can serve as fences, windbreaks, and/or provide shade for animals and shade-tolerant plants (Fernandez-Bou et al., 2024).
Ecovoltaics: Solar power systems that support ecosystem functions like habitat conservation, biodiversity, and air quality control. It integrates ecological knowledge to understand how solar panels influence both non-living components (such as sunlight, water, and air) and living organisms (like plants, animals, and beneficial soil microbes). The goal is to ensure that solar infrastructure not only generates energy but also enhances ecosystem health and sustainability.
Managed aquifer recharge: Strategy to address aquifer depletion and enhance groundwater sustainability involving engineered methods to increase water infiltration beyond natural processes. Recharge potential can be assessed using geophysical techniques like Aerial Electromagnetics (Knight et al., 2018) to identify subsurface characteristics to choose infiltration basins and drywell injection locations. Monitoring pollutants is essential to protect drinking water and recharge efficiency, including avoiding pollution for public health and low-turbidity water to prevent clogging. Focusing recharge efforts along rivers and floodplains offers natural filtration, minimizes infrastructure needs, and supports riparian ecosystems. Managed aquifer recharge can increase resilience against droughts, decrease flooding risks, and help adapt to climate change. See Table 3.
Agroecology: Agroecology is the integrated study of ecological processes applied to agricultural systems, aiming to optimize interactions between plants, animals, humans, and the environment for sustainable food production. It promotes biodiversity, soil health, water conservation, and resilient ecosystems by incorporating traditional farming practices with modern scientific knowledge. Agroecology emphasizes a holistic approach that considers productivity along with social, cultural, and environmental impacts, offering a pathway for more sustainable and equitable food systems. It advocates for reducing chemical inputs, enhancing biodiversity, and fostering natural pest control and nutrient cycling. Agroecology plays a critical role in addressing global challenges like food security, climate change, and biodiversity loss through an ecologically sound framework for agricultural sustainability (Wezel et al., 2009; Altieri, 2018).
Polyculture: Polyculture is an agricultural practice where multiple crops or livestock species are grown together in the same space, promoting biodiversity and mimicking natural ecosystems. This method enhances soil health, reduces the spread of pests and diseases, and improves resource use efficiency, such as water and nutrients. Polyculture systems are particularly beneficial in smallholder farming, improving resource efficiency and reducing the need for chemical inputs like pesticides and fertilizers (Adamczewska-Sowińska and Sowiński, 2020).
Biochar: Biochar is a solid substance that is produced in a controlled pyrolysis process (heat-induced organic matter decomposition in the absence of oxygen) and has a high content of stable organic carbon although specific characteristics vary strongly depending on feedstock, pyrolysis temperature, and pretreament (Sohi et al., 2010). Production of biochar from agricultural waste products supports a circular economy (Joseph et al., 2021).
Community benefits agreement (CBA): A CBA is a legally enforceable contract, which sets forth a range of community benefits that a project proponent agrees to provide as part of a project. CBAs are often established between developers and coalitions of community organizations to ensure affected residents share in the benefits of development projects.
Community benefits plan (CBP): A CBP is a strategic framework that organizations should develop when applying for funding from the U.S. Department of Energy (DOE) or other agencies. These plans are designed to ensure that projects deliver tangible benefits to local communities, particularly those that have historically faced environmental and economic injustices.
Wellbeing economy: Holistic interpretation of the economy with the fundamental goal of achieving sustainable wellbeing with dignity and fairness for humans and nature. A wellbeing economy is an integrated and interdependent system embedded in society and nature.

(Continued)

TABLE 1 (Continued)

Solidarity economy: Social and economic framework that prioritizes the wellbeing of people and the environment over profit. It encourages community-based institutions like cooperatives, trusts, nonprofits, and enterprises to engage in economic activities that benefit workers, enabling them to support their families while also caring for the planet. Profits are used to promote human flourishing, not individual gain. Key aspects include democratic participation in decision-making, equity across all dimensions, cooperation, sustainability, and pluralism, ensuring that diverse voices and approaches contribute to community resilience and prosperity (OECD, 2021).

and efficient water management (Carlisle, 2016; Atume and Voss-Gonzales, 2022). These vulnerable farmers face growing challenges due to slim profit margins, unpredictable water access, lack of representation in policy-making processes, and farm consolidation.

The large-scale farm consolidation in California poses public risks, such as promoting excessive water use, monoculture, and food insecurity, reducing consumer choices, raising food prices, and threatening the resilience of the food system (Woodall and Shannon, 2018). Unlike other rural areas like the Sierra Nevada, which are largely public lands, most land in agricultural regions is privately owned. Despite efforts by land trusts to conserve agricultural land, most of California's farmland lacks permanent conservation protections, raising concerns about the future of small farms and sustainable agricultural practices.

2.2 Legacy of socioenvironmental injustice

California faces multiple socioenvironmental injustices that disproportionately impact low-income communities of color, particularly in rural areas of the San Joaquin, Coachella, and Salinas Valley (Fernandez-Bou et al., 2021b; London et al., 2021). These injustices include failures to uphold the human right to water, inadequate household water infrastructure, unsafe air quality, illegal pesticide exposure, poor housing, lower life expectancy, underrepresentation, limited educational opportunities, limited access to healthcare and public transportation, and lack of green spaces, streetlights, and sidewalks (Gifford and Valdés, 2006; Eissinger, 2008; De Vore, 2009; Balazs et al., 2011; Flegal et al., 2013; Balazs and Ray, 2014; Kissam, 2020; Tejada-Vera et al., 2020; Fernandez-Bou et al., 2021a,b; Flores-Landeros et al., 2022).

2.3 Air quality

California has the worst air quality in the United States, and major agricultural regions (Bakersfield, Visalia, and Fresno-Madera-Hanford) have the worst air quality in California (American Lung Association, 2024). In rural agricultural areas with inadequate environmental monitoring, air quality can become so bad that residents report nosebleeds (Fernandez-Bou et al., 2021b).

Agriculture is the main source of air pollution in the San Joaquin Valley, followed by traffic, pollution from the Bay Area, and wildfire smoke (Cisneros et al., 2017). Aerial or ground pesticide spraying in close proximity to, or directly over, people, homes, and schools, especially when pesticide applications fail to comply with regulatory and public health standards (Bennett et al., 2024) are a main concern for community residents. Due to pesticide drift entering homes, people are also afraid to sleep with their windows open, preventing those unable to afford air conditioning from cooling down during summer nights and exacerbating other health issues (Flores-Landeros et al., 2022). Applying pesticides by plane is allowed in California, although it is banned in multiple countries for being a major threat to public health (Zwetsloot et al., 2018).

Pesticide-laden dust is another major concern. Dust is released during and after farm operations such as tillage (Chow et al., 1992; Clausnitzer and Singer, 1996; Nordstrom and Hotta, 2004; Sharratt et al., 2010) and almond harvesting (for example, Faulkner et al., 2009; Moran et al., 2014; Arzadon et al., 2023). Dust turns the sky of the San Joaquin Valley brown when the almond harvest starts, which in some years is exacerbated by smoke from wildfires.

Fertilizers are major contributors to air pollution. About 10% of the nitrogen from fertilizers becomes gas (Harter et al., 2012), mostly the potent heat-trapping gas N_2O, and a small but significant fraction of NOx, a precursor of ozone, also known as smog (UCS, 2025). The N_2O emissions from agricultural fertilizers in California are around 66 Gg (Xiang et al., 2013; Fernandez-Bou et al., 2023), which represent a social cost around $3,560 million (2020 US$) (EPA, 2023). This amount does not include the cost of other heat-trapping gasses such as methane, of which livestock is the largest emitter in California (CARB, 2024).

The fossil fuel industry, particularly in Kern County, further degrades air quality with its more than 156,000 oil and gas wells, many of them inside and surrounding disadvantaged communities (data available at https://data.cnra.ca.gov/dataset/wellstar-oil-and-gas-wells). Wildfires do not normally burn in the Central Valley due to the lack of forests, although the smoke from fires elsewhere can significantly degrade air quality in the summer and fall, whereas wood burning dramatically decreases air quality in the winter. Agricultural valleys often experience a nocturnal boundary layer inversion that traps pollution along with their topography and stagnant meteorology (Pun and Seigneur, 2001; Brown et al., 2006), increasing health risks for residents.

2.4 Water security and climate change

California's water supply is primarily delivered in a small number of winter storms. After groundwater, the snowpack is the main water storage in state. California's precipitation is projected to fluctuate more between extremely wet and dry years due to climate change (Pendergrass et al., 2017; Swain et al., 2018; Williams et al., 2024). The state's primary water storages—soils, snowpack, and surface water reservoirs—are affected by warmer temperatures, which shift precipitation from snow to rain, reducing snowpack and causing earlier snowmelt (Shukla et al., 2015; Berg and Hall, 2017; Hatchett and McEvoy, 2018; Mote et al., 2018). More precipitation falling as rain and earlier snowmelt forces dams to release water before the main agricultural growing season to avoid major flooding, prompting increased groundwater pumping in the summer. Unsustainable groundwater pumping has created the worst land subsidence in the United States (Levy et al., 2020) and the drying out of thousands of disadvantaged community and small farmer wells in the San Joaquin Valley, threatening groundwater-dependent ecosystems (Saito et al., 2021) and increasing sea water intrusion in coastal areas.

2.4.1 Water rights

California's surface water rights consist of appropriative rights based on the date of first permitted use, and riparian rights tied to land ownership adjacent to water courses (Börk, 2022). Like many Western states that have not adjudicated historic water claims, there are more water rights allocated than actual water supply in many years. The historical overallocation is up to 1,000% of natural surface water supplies in tributaries to the Sacramento and San Joaquin Rivers (Grantham and Viers, 2014). More recent water rights are subject to curtailment during drought years, making their holders switch to groundwater pumping during dry years. About 86% of San Joaquin Valley irrigation districts are overdependent or rely only on groundwater (Espinoza and Viers, 2024).

California's groundwater rights follow a different legal doctrine, wherein overlying users of a common water source share the resource. Yet, this doctrine of "correlative use" has been hard to enforce outside of a legal adjudication, leading to rapidly declining groundwater levels. In response, California passed the Sustainable Groundwater Management Act (SGMA) in 2014. Groundwater basins experiencing the most severe overdraft must achieve groundwater sustainability by 2040 (California Code of Regulations Title 23, Division 3, Chapter 4.5).

2.4.2 Agricultural water use and climate change

Climate change is impacting agriculture in California at multiple levels with different consequences, including water demand. Higher temperatures during the dry months increase evaporation demand from dam lakes and canals. Additionally, higher temperatures have increased evaporative demand (known as reference evapotranspiration) over land surfaces (Albano et al., 2022), leading to greater irrigation demand (Qin et al., 2020; Moyers et al., 2024), and reducing soil moisture (Diffenbaugh et al., 2015; Williams et al., 2015). Agricultural water demand in the San Joaquin Valley in the early 2020s has increased by 4.4% (0.8 km^3/year or 650,000 acre-feet/year) compared with the 1980–2011 period because of increased evaporative demand caused by climate warming (Moyers et al., 2024). Reference evapotranspiration is projected to increase for the Central Valley, particularly during hot, dry summer months (Figure 1).

Higher temperatures during the wet months have decreased the number of chill hours, which are needed by some crops (e.g., pistachios and walnuts) that can no longer be grown in some regions (Pathak et al., 2018). Extreme heat can also kill crops and livestock (Parker et al., 2020).

2.4.3 Domestic wells in agricultural disadvantaged communities

Water supply and security are deeply intertwined with issues of social equity and environmental justice, particularly for disadvantaged and rural farmworker communities (London et al., 2021; Flores-Landeros et al., 2022). These communities often rely on shallower domestic wells that go dry first as groundwater levels decline due to agricultural over-extraction (Perrone and Jasechko, 2017; Rodriguez-Flores et al., 2023). The continued decline of groundwater threatens public health by compromising access to clean drinking water while exacerbating economic and social inequities, as disadvantaged communities suffer water scarcity as large agricultural operations continue to overdepend on groundwater (Espinoza and Viers, 2024).

2.4.4 Nitrate and groundwater quality

Nitrate is a major groundwater contaminant in California. Cesspits and corrals at intensive livestock operations are by far the main pollution sources per unit area of nitrate leaching to aquifers (>3,500 kg nitrate per hectare and year or 3,123 pounds per acre and year), followed by fields irrigated with manure from livestock operations (>2,000 kg per hectare and year or 1,784 pounds per acre and year) (van der Schans et al., 2009). Industrial agricultural crops also contribute to nitrate leaching (for example, almonds leach about 450 kg per hectare and year or 400 pounds per acre and year). Crops account for the largest nitrate contribution at the basin scale, with 54% of the total from synthetic fertilizers and 33% from manure (Harter et al., 2012). In the San Joaquin Valley, rural disadvantaged communities of color experience the highest burden in nitrate contamination (Balazs et al., 2011). There, about 51% of the nitrogen applied as fertilizer leaches to groundwater and 5% becomes runoff (Harter et al., 2012). This inequity in drinking water quality implies a high risk for human health, as long-term intake of elevated nitrate concentration in water can cause serious health hazards in children (such as blue baby syndrome) and other vulnerable populations (Ward and Brender, 2019).

2.5 Other public health threats

2.5.1 Extreme heat is worsening

Extreme heat is increasingly exacerbated by climate change, with more frequent and intense heatwaves posing significant public health risks, especially for vulnerable populations like the elderly, outdoor workers, and low-income communities (Dahl et al., 2019; Licker et al., 2022; Rosas et al., 2024). Climate models predict more frequent and severe heat events, worsening drought conditions and straining public health infrastructure (Diffenbaugh and Burke, 2019). Extreme heat decreases air quality by generating more ground-level ozone, increasing hospitalizations and mortality (Schwarz et al., 2021; Rahman et al., 2022).

2.5.2 Mental health impacts are increasing

Climate change is worsening mental health, particularly in rural and agricultural areas where rising temperatures, drought, and wildfires cause stress, anxiety, and depression among farmers, farmworkers, and communities who face economic instability and environmental degradation (Hayes et al., 2018; Rosas et al., 2024). Climate-induced disasters, such as floods, prolonged droughts,

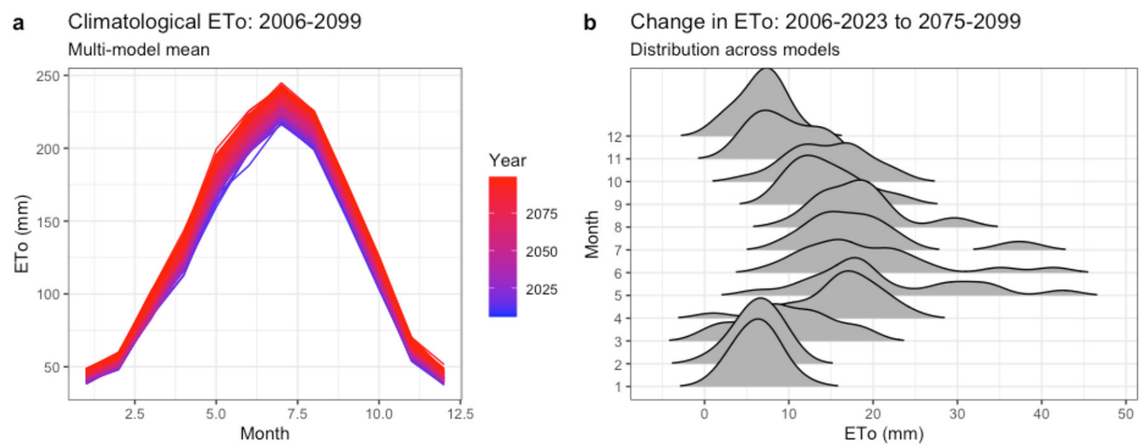

FIGURE 1
Projected reference evapotranspiration (ETo) for three macroscale basins encompassing the Central Valley (Sacramento, San Joaquin, and Tulare), from 20 downscaled CMIP5 models using MACAv2. **(a)** Multimodel mean climatological reference evapotranspiration from 2006 (blue) to 2099 (red). **(b)** Projected change in reference evapotranspiration across the 20 models from 2006–2023 to 2075–2099 for each month.

and wildfires, disrupt communities, leading to increased rates of post-traumatic stress disorder (Zhao et al., 2024).

2.5.3 Food and nutrition insecurity affects farmworkers

Food and nutrition insecurity is common among farmworkers and low-income communities in agricultural areas of California. It is associated with income, education, age at immigration, and depressive symptoms (Matias et al., 2020). Contributing factors include international trade and immigration policies, low wages, undocumented status, land consolidation (Brown and Getz, 2011; Minkoff-Zern, 2014), lack of access to healthy food, and systemic inequities in food access (Ro and Osborn, 2018). Food and nutrition insecurity increase public health costs for California by increasing cardiovascular disease, type 2 diabetes, and obesity, especially among women (Ro and Osborn, 2018). In parallel, around 30% of the available food in the United States is wasted (Cuéllar and Webber, 2010; Dalke et al., 2021), leading to massive waste of water, energy, and pollution of natural resources.

2.5.4 Mosquitoes are bringing new diseases under climate change

Agricultural expansion and urbanization can disrupt natural landscapes, reducing biodiversity and altering ecological dynamics, which often regulate mosquito populations. The decline in biodiversity, particularly natural predator species, creates conditions that support the proliferation of disease vectors like mosquitoes, leading to an increase in vector-borne diseases, including malaria, dengue, West Nile virus, and Zika, some of which are already present in California (Kilpatrick et al., 2010; Ostfeld and Keesing, 2012). Agricultural intensification and human-altered landscapes can create optimal breeding grounds for mosquitoes by increasing standing water and breeding sites while reducing predator populations (Guo et al., 2019).

2.5.5 Valley fever (Coccidioidomycosis) prevalence is growing

This fungal disease, caused by *Coccidioides* spores found in soil, is becoming more prevalent as climate change leads to drier conditions and more dust storms in agricultural regions of California, especially affecting Hispanic farmworkers. When soil is disturbed (normally by tillage and other agricultural activities), spores become airborne, increasing infection risks. Inhalation of spores can cause respiratory symptoms including fever, cough, and fatigue. The disease affects the lungs and can lead to severe respiratory issues, especially in immunocompromised individuals (Gorris et al., 2019; McCurdy et al., 2020).

2.6 Subsidence

Subsidence is the sinking of the ground, primarily caused by excessive groundwater extraction in agricultural areas like the San Joaquin Valley. As aquifers are overdrawn, the compacting of underground sediments leads to land subsidence, which can damage infrastructure, reduce water storage capacity, and increase flood risks (Levy et al., 2020; Fernandez-Bou et al., 2022). This issue has worsened due to prolonged droughts and continued groundwater depletion, especially over San Joaquin Valley's Corcoran clay layer. By 2019, subsidence in California had caused 15% of permanent groundwater storage loss (158 km^3 or 128 million acre-feet). This permanent loss is approximately equivalent to the water capacity of the 12 largest dam lakes in California (Faunt et al., 2024).

2.7 Ecosystems

California is one of the most biodiverse regions in the world, yet its biodiversity is threatened, and some rare species have already been lost forever (Zachos and Habel, 2011; California Department of Fish and Wildlife, 2021). Following the arrival of Europeans to California, especially after the Gold Rush Mining Era in the 1850's, the loss of tribal land stewardship and the reconfiguration of California's landscapes led to a loss of California's biodiversity and natural resilience to extreme events, such as floods, droughts, and extreme heat (Anderson, 2005). Agricultural regions were dramatically transformed. For example, the San Joaquin Valley lost 95% of its original wetlands (Garone, 2011).

Inadequate resource management and California's growth have threatened ecosystems, especially rivers. Human alterations have caused persistent ecological problems, such as disrupted environmental flows and water temperatures critical for species like salmonids, whose climate resilience has declined due to habitat degradation (Munsch et al., 2022). Historical human activity complicates ecosystem restoration, highlighting the need for informed management (Scarborough et al., 2022). Regulatory challenges and hydrologic variability further complicate setting effective environmental flow targets, as past water management has disrupted natural streamflow patterns (Lane et al., 2017; Dourado and Viers, 2024). Addressing these socioecological dynamics requires transdisciplinary approaches.

The California Environmental Flows Framework (CEFF) emphasizes the need for a statewide approach to protect ecological functions by establishing flow metrics that account for the natural variability of river systems (Grantham et al., 2022). However, while these frameworks aim to enhance ecological integrity, the challenge of implementing them effectively across diverse landscapes remains, as many streams still lack adequate flow protections due to funding and interest disparities (Stein et al., 2021). In addition, human-caused climate change has roughly doubled the area burned in Western US forests (Abatzoglou and Williams, 2016), with 37% of the area burned since 1985 directly attributable to the 88 largest fossil fuel and cement manufacturers in the world (Dahl et al., 2023). Climate change also altered species evolution through selection pressures such as more frequent droughts. These conditions lead to heritable earlier flowering times in plants, which disrupts the patterns of migratory animals and pollinators that depend on them (Franks et al., 2007; Kudo and Cooper, 2019).

2.8 Energy

The energy sector's reliance on fossil fuels has heavily contributed to severe climate change impacts and other environmental and public health issues. California's power sector contributes 16% of the state's carbon emissions (CARB, 2024). While the state no longer operates coal plants, gas plants made up 40% of the in-state electricity generation in 2023 (SEIA, 2024). The impact of climate change, notably the increasing frequency and intensity of extreme weather events, has serious impacts to grid reliability, energy security, and energy affordability. Water-related electricity use in California represents about 19% of the total electricity used in the state. Water end uses (heating, cooling, pressurizing, and industrial processes) represent about 14%. California water agencies consume 5.1% of the state's electricity, making them one of the main electricity users in California (Todd et al., 2020).

In California, the growing number of heatwaves, wildfires, and atmospheric rivers reveal the significant impact of extreme weather events on the power grid. For example, a massive heatwave in August 2020 resulted in a drastic increase in electricity demand, which eventually led to rolling blackouts affecting over 800,000 households across the state. Subsequent summers have also seen close calls for rolling outages.

The growing risk of wildfires has led to more frequent Public Safety Power Shutoffs, planned power outages by utilities to reduce wildfire risk from electricity infrastructure. While there are protections for California residents against shutoffs when temperatures exceed or fall below certain hot and cold thresholds, respectively, there is still the risk of customers having power shutoffs in hot temperatures below those thresholds (CEPC and NEADA, 2024). While issuing a Public Safety Power Shutoffs can reduce the ignition risk of destructive wildfires, the decision is based on risk-benefit analysis, as Public Safety Power Shutoffs can shut power off to vulnerable populations (e.g., elderly) reliant on electric medical equipment or extreme heat prevention (e.g., through air conditioning) (Huang et al., 2023).

Energy affordability is another major issue as electricity bills in California have rapidly increased, primarily driven by utilities' investments in wildfire mitigation, and infrastructure upgrades and additions. Low-income communities and communities of color are particularly impacted by this growing energy insecurity (Memmott et al., 2021). For example, wealthier community members can invest in solar and battery storage to avoid rising costs, but lower-income communities often lack such means. Despite the levelized cost of electricity (LCOE) of solar dropping from \$250/MWh in 2010 to \$45/MWh in 2022, major utility rates have risen an annual average of 8% across the three largest utilities (SDG&E 9%, PG&E 7%, and SoCal Edison 6%).

The transition to clean energy will require land to accommodate new resources and transmission infrastructure. California's planning agencies estimate approximately 25% of the 39 GW of additional solar resources will be built in the San Joaquin Valley by 2035.

2.9 Economy in agricultural regions of California

Agriculture carries plenty of economic risk due to shorter-term impacts (e.g., yearly water allocation, acute drought, floods) and longer-term trends (soil salinization, warmer winters with insufficient chill hours). That is why some agricultural regions such as the San Joaquin Valley have a vulnerable economy because of their dependence on agriculture (Medellín-Azuara et al., 2011; Welle and Mauter, 2017; Pathak et al., 2018). Farmers can partially offset crop losses with crop insurance, but insurance does not normally pay farmworkers' job loss.

California's prevailing agricultural model has incentivized growing and protecting profit, often contributing to negative externalities. This approach conflicts with the Sustainable

Development Goals, as its environmental and social costs can outweigh the benefits (Gomiero, 2018; Cook et al., 2023). However, there are opportunities and public recognition for agriculture to deliver positive environmental and social externalities, such as ecosystem services and improvements in quality of life (Baylis et al., 2008; Cook and Davíðsdóttir, 2021; Fabian and Pykett, 2022). This may involve reducing emissions; as of 2018, the social cost of CO_2-equivalent emissions of agriculture (8% of California's total emissions) was approximately $6,500 million per year (EPA, 2023; CARB, 2024).

Farmland consolidation and absentee land ownership are generalized economic risks in agricultural regions. Non-local corporations typically contribute less to community economies than local farmers who live and spend their earnings locally (MacCannell, 1977). Local farmers and landowners create more positive and larger multiplier effects for the local economies than when local wealth is given to external investors. Active local economies create positive socioeconomic effects and opportunities beyond the agricultural sector. Agricultural communities without local farmers or local landowners tend to lack local economic resilience (MacCannell, 1977; Theodoropoulos, 1990; O'Connell and Peters, 2021).

During the 2012–2016 and 2020–2022 droughts, idle land increased by 5% to 10% in the Central Valley, causing crop revenue losses of $900 million and $1,200 million, respectively (Lund et al., 2018; Medellín-Azuara et al., 2022). Drought-induced cropland idling primarily affected lower-value crops like field and grain crops, while high-value crops such as fruits, nuts, and vegetables, which generate 85% of California's crop farming revenue, were less impacted (Lund et al., 2018). However, every drought differs in its effects. The 2012–2016 drought primarily affected the San Joaquin Valley, while the 2020–2022 drought impacted the Sacramento Valley, particularly rice fields (Medellín-Azuara et al., 2022). Lower-value crops, like irrigated pasture and corn silage for livestock, reduced production due to water scarcity, impacting dairies and beef cattle operations (Escriva-Bou et al., 2024). Low-income agricultural workers were disproportionately affected by the economic impacts, often requiring state assistance to cope with unemployment and childcare needs during droughts (Fernandez-Bou et al., 2023). In a warming climate, these disparities are likely to increase, necessitating stronger safety nets and support systems for vulnerable communities (Medellín-Azuara et al., 2024).

2.10 Education, outreach, and representation

Systemic inequities significantly impact education, training, and outreach in California. Disadvantaged communities face a variety of challenges, such as poverty, linguistic isolation, and lack of critical infrastructure (OEHHA, 2021). For example, many children in Central Valley farming communities struggle to concentrate in school due to hunger, unsafe living conditions, and lack of basic amenities like clean drinking water and transportation. Additionally, issues such as extreme weather conditions and poor infrastructure exacerbate educational inequities by making it difficult for students to attend school regularly or engage in learning environments (Gunier et al., 2017; Fernandez-Bou et al., 2021b). Even if schools in these areas receive adequate funding or state-of-the-art technology, the underlying socioeconomic issues continue to undermine educational outcomes (Pastor Jr et al., 2006). Family members' legal immigration status also affects children in farmworker communities, even if they are US citizens themselves. Fear of deportation for individuals of varying legal migration status creates an stressful environment for children, and it has led to school districts in the region reporting higher than average truancy statistics.

Language barriers and time constraints complicate outreach efforts and access to education for farmworkers and low-income residents, making it challenging for them to engage in training programs. Educational initiatives often fail to address the real needs of these populations, as they do not consider the everyday challenges residents face, such as transportation difficulties, job insecurity, and the cost of living. This disconnection between state-level educational reform efforts and local realities has perpetuated disparities in educational access and success (Drake, 2014; Cheney et al., 2022; Moctezuma, 2023).

Outreach programs designed to support students in underserved regions have shown some promise. However, outreach and training efforts remain insufficient, as many fail to fully leverage community-based knowledge or integrate broader systemic solutions into their initiatives. These challenges point to the need for more comprehensive and culturally sensitive approaches to improve representation, education, and training in California's disadvantaged communities (Fernandez-Bou et al., 2021a). Disadvantaged and unincorporated communities remain underrepresented in groundwater management, media, and scientific research, leading to inadequately designed policies (Bernacchi et al., 2020; Dobbin and Lubell, 2021; Fernandez-Bou et al., 2021b).

3 Framework

3.1 Methodology

This Framework was coproduced through literature review and our team's shared collective experiences during several years of engagement with California's growing cropland repurposing community of practice and scholarship. This work draws from participant observations at outreach events, community workshops, and direct interactions since 2019. This informal, iterative coproduction process combined with an evidence-based model for knowledge creation informed by experts and practitioners led to the development of the Framework that orbits around the necessities of the communities and groups it aims to serve (Balazs and Morello-Frosch, 2013; Djenontin and Meadow, 2018; Miles et al., 2022; Bandola-Gill et al., 2023; Hurst, 2023; Ornelas Van Horne et al., 2023).

This study supports the Framework with a literature review and the knowledge of our team, which includes scientists, community leaders, and other experts in cropland repurposing, socioenvironmental justice, water, drought, water policy, sustainable agriculture, climate, climate change, small and family farmers, land trusts, disadvantaged communities, nonprofit work from organizations ranging from grassroots to international, Indigenous knowledge, and environmental and

TABLE 2 Organization of the coproduction of the Framework.

Who	Description	Role
Participants	People representing groups affected by cropland repurposing or other topics related to it.	• Participate in workshops, outreach, and informational events. • Share concerns of their lived and professional experiences or of the groups and communities they represent. • Participants are informed that their comments and suggestions can be used to inform science and policy.
Contributors	Experts, practitioners, and scientists with knowledge and experience related to cropland repurposing and/or other topics essential to its success.	• Same tasks as participants. • Revised the Framework and made multiple suggestions to include their perspectives. • Credited in the acknowledgments.
Coauthors	Experts, practitioners, and scientists with knowledge and experience related to cropland repurposing and/or other topics essential to its success. These topics of expertise include Agriculture, Clean industry, Climate, Climate change, Community, Education, Environmental Justice, Farmer perspectives, Farmworker perspectives, Habitat, Health, Renewable energy, Social Justice, Traditional Ecologic Knowledge (TEK), Systems thinking, Urban perspectives, and Water. Some coauthors work with direct engagement with participants.	• Same tasks as participants. • Revised the Framework and made multiple suggestions to include their perspectives. • Contributed with writing, drafting, or critically revising the manuscript. • Approved the final version of the Framework. • Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
Core team	Small group of scientists, cropland repurposing experts, and practitioners.	• Same tasks as coauthors and participants. • Coordinated synchronous and asynchronous work. • Structured the first version of the outline that was modified through iterations with coauthors and contributors.

habitat conservation and restoration. We employed a systems approach that includes diverse perspectives and priorities. We devoted careful attention to issues related to socioenvironmental justice in disadvantaged agricultural communities, the future of farming, and the fundamental limitations of our natural resources systems. In doing so, this study aims to provide a best practices framework to guide academics, policymakers, and current and future practitioners based on lived experiences, firsthand information, and peer-reviewed science.

In 2023, the core team outlined some ideas based on their shared knowledge and the exchange of information with participants of cropland repurposing outreach events. This outline aimed to guide the interactions with the whole team of coauthors and contributors (Table 2). From January to October 2024, the core team, coauthors and contributors reviewed and revised content through multiple virtual and in-person meetings. In May 2024, 33 team members reflecting a range of different participation roles—from core team to participants—attended a workshop facilitated by the Watershed Solutions Network, using consensus-building and systems thinking approaches to refine ideas. Agreement on the Framework was measured via a Likert scale (0 to 5), with an average score of 4.4. After resolving any outstanding disagreements, the Framework was finalized and revised between June and September 2024. All coauthors and contributors confirmed their support for the final version of the Framework.

A major venue of interaction for the Framework and study collaborators, since 2022, has been the Multibenefit Land Repurposing Program (MLRP) of the California Department of Conservation. MLRP has become the main platform for cropland repurposing policy coordination. MLRP enhances regional capacity to shift irrigated agricultural land toward uses that reduce groundwater reliance and provide community and environmental benefits, such as habitat restoration, green areas, and climate resilience. The Department of Conservation has awarded so far about $75 million over two rounds to eight regions (groundwater sub-basins), known as block grantees, working with diverse groups to address water scarcity and socioenvironmental justice. Several of our authors are involved in MLRP. All MLRP block grantees are required to engage with farmers, community members, environmental groups, and other interested parties. In 2024, California's Proposition 4 passed creating a $10 billion bond that will provide $200 million for MLRP.

3.2 The need for a just transition

The creation of this Framework is anchored on the just transition theory. A just land transition addresses polluting emissions, systemic injustices, and ecosystem recovery while providing equitable benefits to communities (UCS, 2025). This shift from unsustainable agricultural practices to holistic sustainability and local governance supports those most affected, including farmers, farmworkers, and landowners, through education, retraining, and resource access. It promotes socioenvironmental justice and ensures that the benefits of sustainable practices are shared equitably, fostering stronger local economies with minimal negative impacts. The just transition movement originated from labor unions and environmental justice groups in low-income communities of color to emphasize that changes to greener economies should not harm workers or community health (Newell and Mulvaney, 2013; Heffron and Heffron, 2021; Wang and Lo, 2021).

Since 2015, interest in just transition has grown in social sciences, with a focus on carbon-intensive industries like mining and fossil fuels, and to use it as a frame of analysis (Henry et al., 2020; Bainton et al., 2021; Stark et al., 2023). Agricultural regions of California can showcase the application of the just transition theory as both a frame of analysis and a basis for policy shifts while also expanding the application of just transition framing to examples beyond shifting from mining and fossil fuel industries to clean energy (Jenkins et al., 2020).

Our Framework also is inspired by targeted universalism (powell et al., 2019) for policy and social change. Targeted universalism recognizes that different groups have unique challenges in reaching universal goals. It involves setting universal goals for all, while developing targeted strategies that address the specific barriers and needs of different groups, ultimately working to eliminate structural inequities and to create more equitable outcomes across diverse populations.

3.3 How to use the Framework: objectives and best practices

The Framework introduced in the next two sections provides systems-level guidance to understand and implement cropland repurposing, based on local perspectives and expert practitioner experiences to optimize both public and private benefits. The overarching goal is to facilitate the transition to a water-sustainable agricultural sector by promoting green economic alternatives and a healthy environment in traditionally underserved agricultural regions. This approach aims to create equitable opportunities for local residents, enhance environmental health, and improve safety and security before extreme climatological events, while fostering resilience and reducing risks for local farmers and generating multiple benefits for society.

The Framework is founded on six objectives and specific details presented in Italics (Section 4: what we want to see). Objectives are guided by seven overarching best practices (Section 5: how we want the objectives to be achieved) recommended to help reach those objectives. Each of the main best practices has a set of specific implementation strategies presented in Italics at the end of each main best practice subsection. Using this set of best practices is particularly recommended when public funds are used to create public benefits by incentivizing cropland repurposing. This Framework is meant to be maintained dynamically through regular updates to incorporate diverse perspectives and needs, emerging technologies, and the results of new policies.

4 Objectives

This section outlines the objectives of our coproduced Framework. These objectives can serve as priorities of "what we want to see" in land repurposing decision making to guide the design of multibenefit actions and landscape planning. Additionally, they provide a reference for scientists, guiding research efforts toward developing robust and meaningful understanding of land repurposing, addressing the complexities of the system, accounting for climate change considerations, and supporting the implementation and adaptive learning.

4.1 Socioenvironmental and economic justice in the land surrounding vulnerable communities

Justice and equity for vulnerable communities by addressing historical injustices, ensuring compliance with the legal standards for water security (quality, quantity, affordability, and accessibility), air quality, odors, pesticide exposure, dust exposure, nitrate leaching, extreme heat exposure, climate justice, and other local public health risks.

New socioeconomic opportunities for local businesses, for farmworkers that may lose their job due to loss of irrigated cropland, and for the local population through green economy and sustainable development. Opportunities informed by community priorities, aligning economic activities with the health of communities and ecosystems, and supporting local and circular economies with the objective of reducing poverty and increasing the local median household income.

Equitable access to land and natural resources for local residents by expanding climate change resilience infrastructure such as green spaces, trees for shade, community resilience centers, and recreational opportunities. Water security for all in rural and urban areas, including on-farm farmworker housing. Respect and uphold tribal sovereignty and self-determination over ancestral tribal lands and water resources for Indigenous Americans.

4.2 Ecological resilience and sustainability

Restoration and permanent conservation of native habitats to enhance ecosystem functions considering a holistic multispecies approach for landscape-scale habitat connectivity and to protect endangered species. Respect and support for Indigenous traditional ecological knowledge.

Green infrastructure around agricultural communities to improve water security while reducing agricultural dust, pesticides, malodor, and wildfire smoke. Protection against extreme climate events such as wildfire, floods from extreme precipitation and rapid snowmelt, droughts, and extreme heat.

Responsible and sustainable management of natural resources to fulfill present needs while ensuring future generations can also meet theirs.

4.3 Sustainable agriculture based on agroecology principles

Healthy, economically, and ecologically sustainable farming practices for farmers, farmworkers, the agricultural sector, and collective wellbeing based on agroecology and equity.

Fair agricultural leases and prevention of land speculation to minimize the economic impact on leasing farmers. Economic resilience especially for small and medium family farmers and for farmworkers that minimizes negative socioeconomic impacts of loss of irrigated cropland on them. Sustainable agricultural water footprint. Healthy soils that require less fertilizer.

Improved employment conditions, public health, and safety for farmworkers. Improved access to financial support, markets, and technical expertise. Culturally and environmentally appropriate agricultural activities.

4.4 Funding, scalability, and replicability

Funding sufficient to holistically implement land repurposing at the scales required for equitable land, water, and air security, and for *a well-planned transition to a green economy that creates job safety and job security. Initiatives that scale up from local to regional levels while respecting local priorities.*

Landowner engagement and broad participation in cropland repurposing to facilitate scaling up projects and spatial project continuity. Market forces balanced with planned changes to support farmers' sustainability and transition.

Democratic and equitable access to information to avoid lack of preparedness to this change that can harm small and medium farmers. Green economy and clean energy approaches that equitably improve local economies.

4.5 Leadership, accountability, and representation

Collective action coordinated across government institutions for effective change. Bottom-up leadership and guidance with involvement from all interested parties, not just land or water owners. Plurality and representation of local people's points of view in regional development plans. Grassroots groups that have the capacity to organize locally and advocate for community needs.

Non-extractive information exchange with low-income and other vulnerable groups. Robust data monitoring and proof of benefits. Compliance with current law, including pesticide application regulations, Clean Water Act, and labor laws. Reduction of poverty and higher local median household income. Energy resilience for the regions where the energy is generated. Agricultural economic models that account for negative externalities.

4.6 Multiple benefits to address other social needs

Food and nutrition security by fostering crop production for a healthy human diet and by reducing food loss and food waste, and local farmers' markets to facilitate food access. Equitable access to land and resources, especially in areas experiencing systemic inequities in food access. Stronger relationships between the general society, agricultural communities, and the environment to foster better land stewardship. Connection between society and the sources of their food so that people can broadly understand the dynamics of agricultural communities and environmental justice for sustainable land management.

Solutions for co-occurring public health issues, including mental health, physical exhaustion due to extreme climate conditions, malnutrition due to lack of food access, asthma, affordability and access to health care, and other common problems. Affordable housing that addresses specific local needs and culture. Educational opportunities for local residents to increase the labor market options and to promote more local businesses.

Green economy development around disadvantaged communities coordinated with and approved by the communities after a transparent process including trusted local grassroots and community-based organizations. Green economy projects that address local economic, social, and environmental priorities, without creating negative side effects including pollution, odors, noises, excessive traffic, and other problems.

Local food production. Reduction in food waste and food loss. Just land transition that reduces heat-trapping emissions, rectifies systemic injustices, and delivers equitable benefits.

5 Best practices

This section discusses the best practices identified by our Framework to help implement holistic solutions that fulfill the objectives. Each subsection represents one overarching best practice that is discussed through literature review, and then we present specific implementation strategies (in Italics) with our coproduced recommendations within that overarching topic.

5.1 Prioritize public health

Cropland repurposing projects should ensure no harm to public health while prioritizing meaningful improvements to ensure compliance with water and air quality standards, and to promote climate justice. The holistic implementation of "One Health" approaches that integrate human, agricultural, and ecosystem health can enhance resilience and health security (Zinsstag et al., 2011; Destoumieux-Garzón et al., 2018; Miller et al., 2022), and decrease public health costs (Häsler et al., 2013).

Air quality in agricultural regions is influenced by land use practices (Box 1). Pesticide use near disadvantaged communities remains a health concern, but legislation (e.g., AB 1864 regulating pesticide near schools, Connolly, 2024) is advancing toward reducing toxic exposure for vulnerable populations. It is essential that pesticide regulations are enforced to stop illegal spraying over people, in close proximity to residential areas and schools, and with banned substances (e.g., Flores-Landeros et al., 2022; Bennett et al., 2024). Projects should decrease nitrogen losses to the environment as nitrate to groundwater and as N_2O and NOx gasses to the atmosphere. Nitrogen pollution reductions can improve air quality, water quality, and decrease heat-trapping gas emissions. Improving transportation near disadvantaged communities includes the Advanced Clean Fleets regulation (California Code of Regulations, Title 13, sections 2013 to 2016) to reduce transportation emissions by transitioning fleets to electric vehicles, yielding both climate and public health benefits.

Green infrastructure projects can be used for prevention and mitigation of natural disasters, such as floods and the effects of wildfire smoke, to improve air and water quality, and to protect communities before extreme heat and other threats intensified by climate change (Chen et al., 2019; Venkataramanan et al., 2019; Tomson et al., 2021). Developing infrastructure such as affordable drinking water systems, safe housing, and community resilience centers helps build resilience against the increasing frequency of extreme weather events (Pamukcu-Albers et al., 2021). Projects like these also support climate justice by addressing long-standing socioenvironmental inequalities.

Habitat restoration, including wetlands, helps control vector-borne diseases (Keiser et al., 2005). Increasing biodiversity supports mosquito predator populations and disrupts vector

BOX 1 Project example 1: Buffer around a disadvantaged community in Madera County.

Project: Buffer zone at La Viña **Location**: La Viña, CA (Madera County)
Description: La Viña, an unincorporated disadvantaged community in Madera County, is receiving a project for a buffer zone around two sides of the community with a tree belt to physically separate the residents from the walnuts and almond orchards on the south and east of the community. Tree belts are natural barriers to decrease pesticide drift into people's homes, increasing local air quality (Zaady et al., 2018). The Madera Multibenefit Land Repurposing Program is partnering with La Viña residents supported by the Leadership Counsel for Justice and Accountability and Davis Diversified Farms on this 5-acre pilot project. The project will convert four rows of almond and walnut orchards into native pollinator habitat, creating a 30-m (100-ft) buffer between the homes and the farm aiming to improve soil and air quality, reduce pesticide use, and conserve water. Approved in 2024, the habitat installation will be completed in 2025, with ongoing benefits expected until 2035, alongside the La Viña Mobility Improvement Project starting in 2026–27. Funding from Madera MLRP.

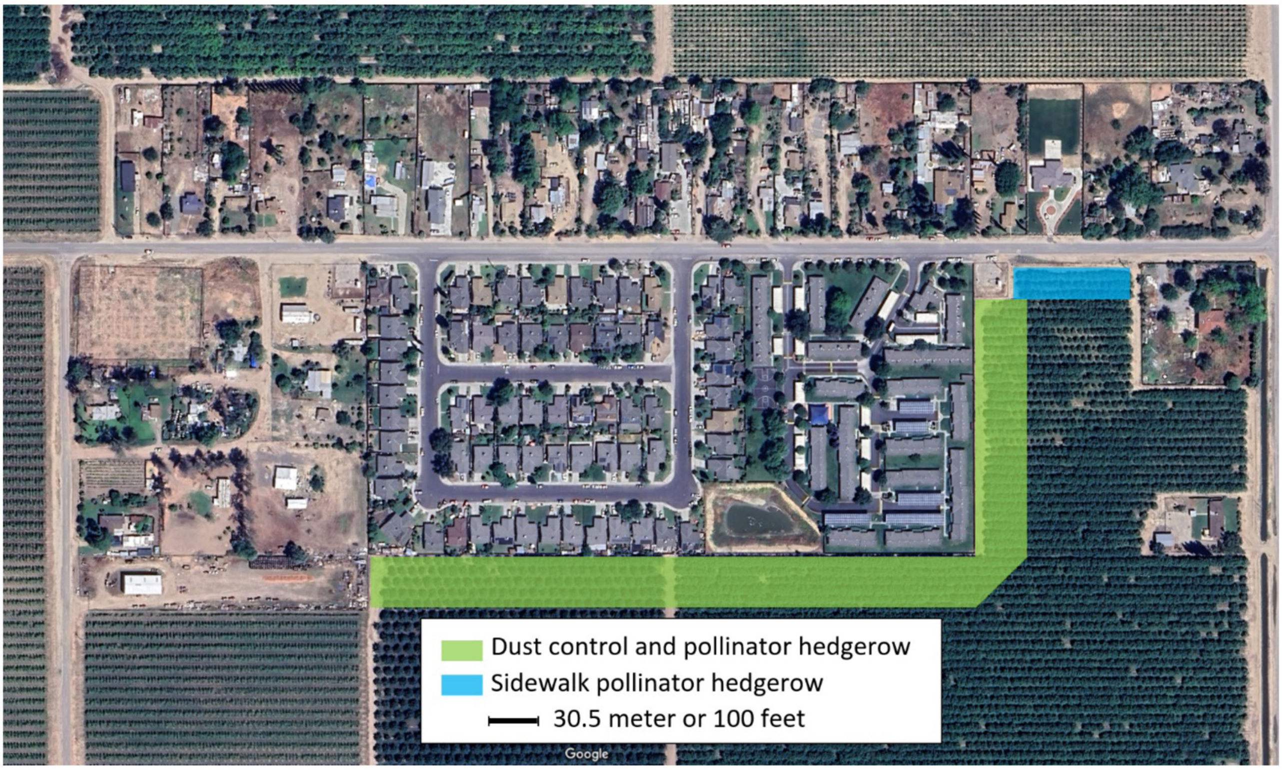

Image courtesy of Zanjero.

lifecycles, limiting mosquito populations and reducing prevalence of diseases like West Nile virus and dengue that are already present in California (Ostfeld and Keesing, 2012; CDC, 2024; WestNile.ca.gov, 2025). Sustainable land use practices such as agroforestry and rewilding disrupt vector habitats, reducing reliance on pesticides and improving ecosystem and public health.

Projects can also improve local food and nutrition security (Carney et al., 2012). In addition to increasing local food availability, food loss and food waste should be prevented. Recycling organic waste and promoting the sustainable management of food resources can reduce the environmental impacts of agriculture and improve the efficiency of food systems. Preventing food waste enhances food security and aligns with climate justice goals by reducing heat-trapping gas emissions associated with waste decomposition (Zedler and Kercher, 2005). Other technologies such as aeroponics can be a good solution to implement in community gardens in disadvantaged communities to increase food and nutrition security while decreasing crop water footprint and decreasing the reliance of land to grow food. Depending on the crop, aeroponics towers can reduce land use by 98%, water use by 95%, fertilizer use by 60%, and pesticide use by 100% while increasing plant yield and nutrition density (Lakhiar et al., 2018; Kumari and Kumar, 2019).

Success in adopting this best practice can improve quality of life in disadvantaged areas, decreasing taxpayer costs in public health and emergencies, decrease litigation costs by decreasing controversy, dramatically decrease the costs of disaster relief (wildfires, air quality, drought, floods) thanks to investments in resilience, and reduce hunger and food & nutrition insecurity for farmworkers and other vulnerable groups. Prioritizing this best practice can reverse the current status quo of a century old legacy of socioenvironmental injustice in agricultural regions (Dobbin and Lubell, 2021; Fernandez-Bou et al., 2021a).

5.1.1 Ensure water security, air quality, and climate justice

Repurpose cropland to ensure compliance with the legal standards or better for water security (quality, quantity, affordability, and accessibility), air quality, odors, pesticide exposure, dust exposure, nitrate leaching, extreme heat exposure, climate justice, and any other local public health risks.

BOX 2 Project example 2: Wuk'nain restoration project in Wukchumni Tribe ancestral lands in Tulare County.

Project: Wuk'nain restoration project **Location**: Visalia, CA (Tulare County)
Description: The Wuk'nain Riparian and Wetland Habitat Restoration project (Tulare County), led by the Wukchumni Tribe in partnership with Quaker Oaks Farm, will restore 10.7 acres of riparian woodland, willow forest, and freshwater marsh in the Deep Creek floodplain. With $500,000 in funding, the project will enhance native habitats, increase pollinator areas, and promote groundwater recharge. It incorporates educational, recreational, and workforce opportunities for local communities and Tribal members, while revitalizing traditional land uses. The project also focuses on native plant cultivation, ecological restoration, and potential flood protection, benefiting both the ecosystem and local communities. While returning land back to the Wukchumni is not part of this project, this is an important milestone for the Tribe. Funding from Kaweah MLRP.

5.1.2 Invest in fundamental and green infrastructure for justice and against extreme events

Develop fundamental infrastructure in underserved agricultural communities, including affordable drinking water, sewer systems, safe housing, health centers, community resilience centers, public transportation, parks, sidewalks, streetlights, broadband, education centers, and compost hubs. Create green infrastructure to reduce flood risk (e.g., from above-average precipitation to atmospheric rivers), drought effects, and exposure to extreme heat, including green areas, parks, trails, climate resilience centers, and community recreation areas. Promote climate change adaptation and mitigation strategies tailored to local conditions.

5.1.3 Promote safe agriculture around communities

If agriculture is maintained inside or around disadvantaged communities, it should be safe for residents to protect water and air security in revitalization belts (buffer zones) of about one mile around the communities, prohibiting the application of hazardous pesticides by aircraft (as it is forbidden in other countries) to dramatically increase health and environmental benefits and decrease public health costs for taxpayers.

5.1.4 Support food and nutrition security, and prevention of food waste and loss

Prevent hunger by making food available and promoting community gardens, especially in food deserts and areas affected by injustice in food access. Prevent food loss and food waste, promote recycling of all organic waste, and ensure food and nutrition security for agricultural workers.

5.2 Prioritize cropland repurposing in socioenvironmentally vulnerable locations

Systematically locating adequate cropland repurposing projects near disadvantaged communities is an opportunity to maximize multiple benefits with public funding (UCS, 2023). Projects including green economic activities, groundwater recharge

TABLE 3 Managed aquifer recharge (MAR) advantages, risks, and best practices.

Advantages	Risks	Solutions and Best Practices
Disadvantaged communities		
Enhances water access and security for underserved communities. Long-term improvements in groundwater quality through proper management. Dilution of pollutants to safe levels. Increases resilience to droughts and floods in vulnerable areas.	Pollutant mobilization can disproportionately affect these communities. Lack of financial and technical resources for monitoring and maintenance. Recharge of polluted or turbid water can degrade groundwater quality (e.g., nitrate leaching, mobilization of pathogens, and metals).	Use clean water on clean soils (Castaldo et al., 2021). Analyze hydrogeology and soil pollutants before doing any recharge near disadvantaged community wells. Locate MAR projects within drinking water wells capture zones (Marwaha et al., 2021). Engage local communities in design and implementation of MAR projects to ensure alignment with their needs. Have mitigation strategies in case of water pollution peaks recharge events. Finance regular monitoring of nitrate, pathogens, and metals and technical assistance (Community Water Center et al., 2025).
Flood mitigation		
Reduces downstream flood risks by capturing excess water. Provides recharge opportunities during heavy streamflow. Can save disaster relief costs.	Poor floodwater management can lead to urban flooding. Floodwaters may carry pollutants like heavy metals and oils.	Design recharge basins with adequate capacity. Use natural floodplains with coarser soil texture. Monitor for flood-induced pollutant mobilization. Combine MAR and ecosystem restoration.
Drought resilience		
Enhances groundwater availability during droughts. Supports long-term aquifer recharge.	Over-reliance on groundwater may degrade water quality. Limited recharge opportunities during megadroughts.	Recharge during wet years for drought buffer. Integrate drought planning into MAR strategies. Utilize high hydraulic loadings to promote recharge and improve denitrification (Waterhouse et al., 2021).
Ecosystem benefits		
Supports riparian ecosystems by maintaining baseflows. Enhances habitat restoration efforts.	Potential disruption to local ecosystems if not properly managed.	Prioritize natural floodplains for recharge. Work with environmental groups to ensure MAR contributes to biodiversity and habitat restoration. Monitor ecosystem health. Integrate MAR with ecological restoration.
Agricultural impact		
Can support crop production by improving groundwater availability for irrigation.	Inconsistent (low) recharge frequency on cropland can increase nitrate leaching.	Use cover crops to absorb residual nitrogen and apply recharge to low-nitrogen areas (Waterhouse et al., 2020). Avoid applying fertilizer before recharge events.
Nitrate reduction		
Decreases nitrate concentrations in groundwater through dilution and reduces nitrogen inputs through new land uses.	MAR, especially Ag-MAR (on-farm managed aquifer recharge), may increase nitrate leaching if mismanaged. Low-frequency flooding can exacerbate nitrate leaching.	Prioritize low-nitrogen croplands and avoid fertilizer application before MAR events (Waterhouse et al., 2020). Prioritize increased flooding frequency to avoid excess leaching due to nitrification (Murphy et al., 2021). Implement cover crops post-harvest to capture residual nitrogen (Waterhouse et al., 2020).
Reduction of other pollutants		
Reduces pollutant concentrations through dilution. Potential multibenefits for ecosystem restoration.	Oils, pathogens, and heavy metals from stormwater or poorly managed runoff can infiltrate. Clogging of recharge basins and drywells can occur due to high water turbidity.	Use pretreatment (sedimentation, filtration) to remove pollutants. Avoid using stormwater with high turbidity or excess contaminants to minimize clogging risks and protect drinking water quality (Maliva, 2020). Recharge with clean water.

basins, or floodplain restoration inside and around communities can promote environmental sustainability, enhance water resources, reduce emissions, provide open space recreational areas, socioeconomic benefits, and support biodiversity (Box 2). They can advance social equity and increase climate resilience by providing affordable clean energy, increase groundwater resources, create jobs, and empower vulnerable communities, while strengthening economic resilience, diversifying local economies, and building capacity for future challenges (Nuñez-Bolaño et al., 2025). Projects can also foster community engagement and encourage active participation, strengthening social cohesion and collective stewardship of natural resources. A recent socioenvironmental analysis about cropland repurposing inside and one mile around small disadvantaged communities of the Central Valley (154 communities, 600,000 inhabitants) estimated that investing $27 million per community for 10 years ($4,158 million per year) would annually increase total income by $11,617 million per year for 30 years and create 62,697 job positions paid 67% more on average (after losing 25,682 lower-paid jobs related to cropland retirement, with a positive balance of 37,015 new jobs). Water use could simultaneously be reduced by about 1.8 km^3 per year (1.46 million acre-feet) (Fernandez-Bou et al., 2023). Repurposing floodplains to prevent floods can also protect people and is at least five times cheaper than the potential costs of disaster relief (Gourevitch et al., 2020). Combining floodplain restoration with other flood-prevention measures such as FIRO (Forecast Informed Reservoir Operations) and MAR (Managed Aquifer Recharge) can strengthen the state's resilience to climate change-induced water challenges (Table 3).

BOX 3 Project example 3: Repurposing dairy to floodplain restoration creating a State Park in Stanislaus County.

Project: Dos Rios Ranch Reserve **Location**: Near Grayson, CA (Stanislaus County)
Description: Dos Rios Ranch Preserve in Modesto, near the disadvantaged unincorporated community of Grayson, is California's largest floodplain restoration project that repurposed 2,100 acres of agriculture (dairy) into habitat at the confluence of the Tuolumne and San Joaquin Rivers. With $40 million managed by the nonprofit River Partners, the project planted 280,000 trees, protected nine priority species, conserved 8.63 million m^3 (7,000 acre-feet) of freshwater, and its construction involved the creation of 250 new jobs in a disadvantaged community. In 2024, it became a California State Park (River Partners, 2024). Multiple funding sources.

Photo credit: River Partners.

Improving socioeconomic and environmental justice in agricultural disadvantaged communities can improve job opportunities and salaries, foster safer working conditions, and increase property value. This can be achieved by increasing green economic opportunities and environmental resilience with sustainable agriculture, habitat restoration, and by promoting adequate infrastructure for project proponents and communities (e.g., streetlights, roads, sidewalks, and sewer systems). Antigentrification policies can also avoid the displacement of long-term residents and small farmers.

Managed aquifer recharge (MAR) for groundwater sustainability is a promising cropland repurposing strategy (Table 3). However, recharge near disadvantaged communities should prioritize clean and sufficient water benefiting community wells, and should be done carefully (Renteria and Lukacs, 2019; Community Water Center et al., 2025). More research is needed to ensure that groundwater in disadvantaged communities will not be polluted by aquifer recharge. Until clean water can be guaranteed within specific recharge sites, a general rule supported by community-based organizations is to avoid recharge in soils with polluting potential in the vicinity of drinking wells. This includes soils with nitrate near dairies, fruit and nut orchards (Lockhart et al., 2013), and sites with toxic pollutants like 123-trichloropropane (Hauptman and Naughton, 2021) and uranium (Renteria and Lukacs, 2019; Fendorf et al., 2020; Lopez et al., 2021). Aquifer recharge can decrease pollution by dilution or increase it by contaminant transport (Edwards et al., 2016; Maliva, 2020; Castaldo et al., 2021).

Returning land and water rights to California Native nations can address historical injustices and promote sustainable land management through indigenous stewardship. Empowering Native communities to apply traditional ecological knowledge fosters biodiversity, cultural heritage, and social equity (Risling Baldy et al., 2024) (Box 3). Integrating Native perspectives into decision-making enhances ecosystem restoration and resilience, and traditional knowledge like cultural burns can reduce wildfire risks and improve forest health (Kolden, 2019; Martinez et al., 2023). Combined with mechanical thinning and prescribed burns, these practices enhance resilience to fires, droughts, and increase water yield (Saksa et al., 2017; Guo et al., 2023).

5.2.1 Protect and enhance disadvantaged communities and their surroundings

Promote a non-extractive green economy with diversified and community-led economic activities. Prevent the displacement of long-term residents after investments in cropland repurposing inside and around underserved regions and disadvantaged communities. Foster agroecology and polyculture for small family farms inside and around agricultural communities.

BOX 4 Project example 4: Allensworth Agroecology Hub with agrivoltaics in a community trust in Tulare County.

Project: Allensworth Agroecology Hub **Location**: Allensworth, CA (Tulare County)

Description: The township of Allensworth is planning to repurpose cropland to transform industrial monoculture into an agroecology hub that will be owned by a community trust and managed by the century-old nonprofit Allensworth Progressive Association. The Allensworth Agroecology Hub has these initial components:

1. Agroecology specialty crops: Promoting regenerative agriculture with diverse crops to sell locally, supporting seed biodiversity and carbon sequestration, and with the farm as a learning center for sustainable farming.

2. Agrivoltaics: Allensworth aims to become energy independent thanks to an agrivoltaics facility of at least 2 MW of installed capacity and batteries. Agrivoltaics leverage on multiple synergies of solar with agriculture, such as increased energy generation efficiency thanks to the cooling effect of vegetation or shading that benefits certain crops and livestock.

3. Beginning Farmer Training Program: A seven-month program that offers training in regenerative agriculture, soil health, business operations, and financial access, specifically for women and people of color.

4. Land Access Program for Farmers: Provides subsidized land access for small-scale farmers, especially people of color, through a cooperative model, offering leases up to 10 years.

5. Water Treatment Technology: Development of affordable water treatment technology to remove arsenic, with the goal of providing clean drinking water and marketing the technology in California.

6. Rabbitry: Rabbit farming to supply meat for local food security and cultural practices.

7. Vermiculture Compost: A large-scale vermicomposting project that uses earthworms to produce nutrient-rich organic fertilizer. Some of the compost will be sold locally to support soil health and regeneration.

8. Agritourism: Attracting visitors through regenerative agriculture demonstrations, including a community store, cultural gardens, and food offerings, helping to support the local economy and reduce barriers to food access.

Image courtesy of the Allensworth Progressive Association. Initial farm project size of 40 ha or 100 acres.

5.2.2 Repurpose agriculture in sensitive environmental areas

Restore historical floodplains, land adjacent to wetlands, riparian zones, and areas near forests or conservation lands such as municipal, state, or federal parks. Create wildlife corridors to enhance habitat connectivity through multispecies approaches and enhance habitat for pollinators. When possible, lands less suitable for agriculture but capable of providing similar environmental benefits should be prioritized for repurposing. Multibenefit aquifer recharge can be compatible with habitat restoration, public health, and groundwater sustainability.

5.2.3 Indigenous sovereignty and justice

Promote tribal sovereignty over ancestral tribal lands and water resources for traditional uses, for permanent environmental protection, and allowing Tribes to choose how to use those resources.

5.3 Transition agricultural practices for sustainability and strategic farming

Cropland repurposing projects should reduce water use, pesticides, and fertilizers, while increasing agricultural ecosystemic functions within landscapes. Strategically planning the composition and configuration of agricultural landscapes can provide ecological and public health benefits by optimizing ecosystem functions (Haan et al., 2021). Transitioning from monocultures to diverse, multifunctional land uses—such as agroecological systems, agrivoltaics, and permanent vegetation cover—enhances biodiversity, improves soil health, and fosters more resilient agroecosystems (Butterfield et al., 2021). These landscapes serve as buffers against climate change by regulating water cycles, reducing erosion, and increasing carbon sequestration. They also promote habitats for pollinators and natural pest control, reducing reliance on chemical inputs like pesticides and fertilizers, which improves air and water quality (Khangura et al., 2023).

Complex landscapes, where natural areas are integrated with agricultural fields, attract more beneficial insects for pest control and support overall biodiversity (Bianchi et al., 2006). The arrangement and proximity of habitat patches are key to maximizing these ecosystem services, contributing to both agricultural sustainability and biodiversity conservation. Fine-grained landscapes, with smaller fields and habitat patches, allow for varied management practices and timing, providing crucial shelter and overwintering habitat for beneficial insects (Haan et al., 2020). Ecological intensification depends on the services provided by beneficial arthropods and other ecosystem contributors, including regulating, supporting, provisioning, and cultural services (Haan et al., 2021). The amount and spatial arrangement of semi-natural habitats—offering shelter, nectar, alternate prey/hosts, and pollen (SNAP)—are crucial at multiple scales, from small crop fields to whole farms, which affect neighboring landscapes (Gurr et al., 2017). Understanding timing and spatial distribution of SNAP resources across seasons enables farmers to optimize pest suppression and other ecosystem services. To fully maximize these benefits, careful planning of landscape composition and configuration can further enhance the value of on-farm habitat diversification. Strategic integration of seasonal wetlands within agricultural landscapes creates vital habitat for migratory birds and waterfowl while simultaneously providing flood management and aquifer recharge benefits. Even small plots of on-farm habitat can serve as critical wildlife corridors for migratory species that have lost most of their natural habitat in intensive agricultural regions. These species can support natural pest control and deliver other agronomic and ecological benefits. Additionally, crops like rice can significantly enhance habitat availability for birds while contributing to food security (Elphick et al., 2010).

Agroecology and regenerative agriculture are potential solutions for holistic sustainable crop and livestock production. Well-managed agroecological systems may result in water use reduction while reducing or eliminating toxic chemical pesticides and fertilizers, thereby reducing air and water pollution (Wezel et al., 2014; Altieri et al., 2017; Khangura et al., 2023). Regenerative practices such as integrating livestock, cover cropping, and maintaining non-crop habitat, have been applied to almond orchards in California, improving total soil carbon, soil nutrients, biomass, species diversity, ground cover, water infiltration rates, and profit (Fenster et al., 2021). Agroecological practices may enhance soil health by increasing soil organic matter content and improving soil structure, leading to improved soil water holding capacity and infiltration, ultimately benefiting the overall on-farm water balance and drought resilience (Sustainable Conservation, 2024). Agroecological practices that may enhance agricultural soil health in California include practices that reduce soil disturbance (e.g., no-till or reduced tillage), increase soil organic matter content through above or belowground biomass growth (e.g., cover cropping, intercropping, agroforestry practices), and increase soil organic matter content through direct organic matter amendment (e.g., compost or biochar amendment, mulching, residue retention). For example, biochar applications increase soil water retention and water use efficiency, and benefits for crop yield and mitigation of hydrological extremes are highest in water limited regions (Burrell et al., 2016; Xiao et al., 2016; Fischer et al., 2019). Biochar can reduce soil bulk density, nitrous oxide emissions, and nitrate leaching (Blanco-Canqui, 2017; Borchard et al., 2019; Kaur et al., 2023), and increase porosity, pH, and nutrient availability (Joseph et al., 2021; Bolan et al., 2023), while alleviating salinity (Ali et al., 2017; Yang et al., 2020).

Composting represents another land use opportunity to manage agricultural and urban organic waste that can reduce greenhouse gas emissions, especially if organic material is co-composted with biochar (Harrison et al., 2024). When applied to soils, compost can improve soil health and increase soil organic matter content while decreasing reliance on synthetic fertilizers through organic nutrient provision (Malone et al., 2023; Hall et al., 2024). Community composting efforts can empower communities to establish a lower circular nutrient economy, by which they recycle locally generated organic waste into local agricultural systems, increasing food sovereignty (De Boni et al., 2022) (Box 4). Smaller, decentralized composting efforts may also have less overall climate impact when accounting for emissions to transport organic material to centralized, industrial composting facilities (Martínez-Blanco et al., 2010). Community composting efforts also present an opportunity for compliance with organic waste diversion laws such as SB 1383 (bill passed in 2016, effective from 2022).

Increased soil organic matter content, if maintained, may lead to soil carbon sequestration, an important climate mitigation strategy (Lal et al., 2015). Application of organic matter amendments such as biochar and compost can sequester soil carbon on agricultural land (Ryals et al., 2015). Improved soil health in agroecosystems has additional multibenefits, including reduced wind erosion from improved soil structure and increased soil cover (Nordstrom and Hotta, 2004), resilience to climate shocks (Lehmann et al., 2020), and improved financial resilience for farmers from diversified systems and silvopasture (Smith et al., 2022).

Cropland repurposing into agroecology, particularly for on-farm water savings, can be reasonably predicted (farmers can expect measurable water savings in a given timeframe) and meaningful (a non-negligible amount of water is saved). However, transitioning to agroecological farm management at scale requires sufficient investment in locally led technical assistance, farming incentives, and education to support farmers and farmworkers. A transition to agroecological management in California, especially in the San Joaquin Valley, can help mitigate challenges faced by a farming community that is very profitable but continuously threatened by farmland consolidation and climate change.

5.3.1 Transition from single soil use to multiple soil uses and agroecological practices

Foster multibenefit agricultural projects that maximize the prioritized public benefits by transitioning from single land use to a mosaic of multipurpose beneficial land uses, such as cropland managed with agroecological principles or agrivoltaics. Invest to support farmers' efforts to adopt agroecological principles.

5.3.2 Support the transition of irrigated farmland to sustainable agricultural water use

Transition to dryland farming, including non-irrigated, non-intensive grazing for positive ecological outcomes and climate benefits, and to less water-intensive crops, including native seed production for habitat restoration and conservation. Foster planting of cover crops or conservation cover.

Address barriers to transitioning to less water-intensive crops and to agroecological systems in general, including market access, technical expertise, labor availability, and financial support.

Facilitate climate-smart transitions in agriculture to create climate resilience and economic robustness for small and medium farmers.

5.3.3 Incentivize the transition in agronomic practices

Promote low or no tillage to decrease dust emissions and other practices to improve soil health. Transition away from reliance on excessive fertilizer. Improve biodiversity and pollinator habitat on agricultural lands, for example with hedgerows or windbreaks. Encourage organic matter amendment application and mulching when possible.

5.3.4 Incentivize voluntary strategic farming plans

Help farmers plan their cropping options within a state farming plan that guides a shift in crop types to ensure food and nutrition security and to decrease economic risk for farmers while minimizing agricultural water use and accommodating climate-smart goals. Prioritize local food.

5.4 Foster a sustainable agricultural economy

Cropland repurposing projects should protect the livelihoods of farming communities, farmers, and farmworkers, especially for small and mid-size farming operations and disadvantaged communities overdependent on agriculture. Ensuring the longevity of projects, especially for leased cropland, is important to sustain the multiple benefits that cropland repurposing can bring to a region. Reducing groundwater demand can help groundwater sustainability agencies to meet legal objectives locally. This transition requires repurposing cropland to less water-intensive uses while minimizing the negative economic impact to farmers and farmworkers. Considering options to maintain agricultural working lands can also help preserve the agricultural identity of agricultural regions, and having multiple uses for the land can facilitate this process. There are many types of agriculture practiced in California and the San Joaquin Valley, and certain farming practices, particularly by underserved farmers that produce food for local consumption, can be part of the solution for cropland sustainability.

Farmers can diversify their revenue streams or decrease their costs by allowing multiple uses of the soil. This approach can create opportunities for incentives, mitigation credits, payment for services, and private partnerships. For example, agrivoltaic systems (dual solar and agriculture systems) can either provide revenues for energy generation or significantly decrease the electricity bills (Abdallah et al., 2024; Fernandez-Bou et al., 2024) (Box 4). Land diversification also serves as a risk management strategy in response to water variability. By maintaining an optimal balance between annual and perennial crops, farmers can mitigate the impact of water shortages during droughts while expanding the area for annual crops when surface water is available (Wartenberg et al., 2021; Quandt et al., 2023).

Funding for conserving and restoring large contiguous areas for landscape-scale habitat connectivity and other ecological benefits can provide incentives for farmers (Rey Benayas and Bullock, 2012; Newton et al., 2021). This strategy involves aligning incentives for landowners in areas where cropland repurposing is most beneficial. Farmers may have different funding sources and incentives for cropland repurposing, depending on their access to surface water, local groundwater restrictions, and other factors. While groundwater scarcity, for example, is creating pressure to take land out of production, individual landowners need meaningful economic incentives to support the long-term conservation and restoration of their land. Incentives may include implementing conservation easements on the land that can help preserve farmers' stewardship of the land, agreements involving compensation over time for ecosystem services provided by restored farmland, or some combination.

Landowner operations can be protected with Safe Harbor Agreements (SHAs), which assure they will not face additional regulatory challenges if they or their neighbors enhance or restore habitats for endangered species. These agreements provide peace of mind for landowners by limiting their liability under the Endangered Species Act (ESA) or the California Endangered Species Act (CESA), even if endangered species move into restored habitats. Habitat restoration can directly benefit agricultural operations, including improved water management, enhanced soil health, and the potential for diversified revenue streams through ecosystem service programs. Initiatives like the Environmental Quality Incentives Program (EQIP) and state conservation grants offer financial support for restoration efforts, allowing farmers to improve their land without bearing the total cost.

Incentivizing local food production or establishing food hubs to connect locally produced food with local markets connects local growers and consumers. These hubs can be planned to produce specialty crops that satisfy local demand, particularly in places where access to larger markets is limited and for cultural reasons (Box 4). Local food production has the potential to meet up to 90% of the US demand, showcasing the opportunity to decrease pressure over some agricultural regions in California that experience unsustainable practices while also decreasing the carbon footprint of transportation and creating agricultural opportunities in other regions (Zumkehr and Campbell, 2015).

The transition of agricultural lands to sustainable practices or other land uses (e.g., clean energy production and conservation) will create job opportunities that require large-scale workforce development and education. As conventional irrigated cropland is repurposed, skilled workers from rural areas and former farmworkers can transition into these roles, enhancing the local economy. For example, workforce development can help with agricultural technification for precision agriculture, agroecology, solar energy, conservation, and native plant production. This shift will create new employment opportunities and foster the development of a more resilient and sustainable economy in agricultural regions.

5.4.1 Protect small and mid-size farmers

Incentivize equipment sharing among small farmers and other initiatives such as cooperatives to facilitate success for small and mid-size farmers. Identify revenue or saving sources like agrivoltaics or decentralized composting for small farmers. Prioritize and enhance water access for farmers practicing socially and environmentally beneficial methods. Protect small and medium family farmers from water and land consolidation.

5.4.2 Prioritize long-term social, environmental, and economic sustainability

Understand the best ways to widely implement long-term sustainable and profitable agriculture practices such as simultaneous land uses like agrivoltaics and agroforestry. Ensure land designated for these projects and practices is under secure tenure for long-term ecological and social benefits, and to avoid the displacement of small, disadvantaged farmers. Agricultural economic models should account for the negative externalities of agriculture to avoid unintended negative effects.

5.4.3 Identify how urban California can support rural regions and agriculture

Urban California can invest in headwater protection and their own food security. For example, cities can invest in watershed and forest management to protect the source of their water, and that helps prevent wildfires too.

Foster urban agriculture and more local access to food production everywhere in the United States to make the country's food system less dependent on California, allowing the cropland transition in California to be safe for everyone.

5.5 Advance equity and center community leadership

Cropland repurposing projects need to follow a transparent process that uses full cost and benefit accounting, including side effects, to understand new land uses (UCS, 2023). A comprehensive accounting of strategic cropland repurposing will demonstrate tradeoffs and impacts on different interested parties, including Tribal nations, rural communities, farmers, landowners, the environment, and local industry. Such assessments should include both positive and negative impacts. The negative externalities of extractive agricultural activities already cost Californians billions of dollars, but they have been institutionally excluded from dominant agricultural economic models. Current and potential negative side effects include economic impacts of groundwater depletion on water security, health and economic costs of water and air pollution, infrastructure destruction due to subsidence, and the social costs of heat-trapping emissions (Fernandez-Bou et al., 2022; Flores-Landeros et al., 2022; EPA, 2023; Perrone et al., 2023). There is growing interest in designing the economy to serve both people and the planet, rather than the other way around, as defined by the concepts of a wellbeing economy and solidarity economy (Table 1, Box 1). This holistic interpretation seeks to prioritize human and planetary needs at the center of our activities, rather than pursuing economic growth as an end regardless of the costs. This approach aims to capture and address the major problems facing the world today, including poverty, inequality, environmental degradation, and climate change (Cook and Davíðsdóttir, 2021).

The distribution of these impacts is a critical concern. Distributive justice is a way of assessing the physical and economic distribution of costs and benefits, often using geospatial and economic analyses to map and measure who benefits and how much. Low-income communities and communities of color have been disproportionately exposed to environmental harm. They should be protected from such future harms and prioritized for specific, intentional benefits in ways that begin to remediate and transform ongoing damage (Siddiqi et al., 2023). But a focus on distributive justice alone cannot offer solutions that advance equity in this way (McDermott et al., 2013). Advancing more equitable planning, land use, and management necessitates attention to the ways that injustices are produced and reproduced. Procedural justice focuses on the social processes that allocate resources and resolve disputes. This can include the ways in which we develop and implement laws, projects, and plans. Procedural justice provides an intervention point to drive more equitable outcomes by broadening who is involved and improving how decisions are made (Seigerman et al., 2023). When done effectively, communities are more well-represented in the pursued benefits and the accepted costs. Procedural justice also involves enforcing legal protections, which is a major concern at present, with families and homes, even children, being illegally sprayed with pesticides, sometimes with highly toxic illegal substances such as chlorpyrifos that was banned from sale and possession in 2020 (Bennett et al., 2024).

At the root of procedural justice is recognitional justice (Seigerman et al., 2023). Equitable decision-making processes that lead to equitable outcomes depend on the recognition and integration of diverse voices and perspectives (Dobbin, 2021). In other words, equitable land use transitions center the leadership of impacted communities and meaningfully engage their expertise in charting a path forward. One main barrier to success is the lack of inclusivity. However there are resources available for similar collaborative processes (Dobbin et al., 2015; Koebele et al., 2024). For example, beyond collaborative governance processes, participatory research also offers a pathway by which frontline communities and their research collaborators can achieve structural change and work toward just outcomes through processes that are inherently non-extractive (Davis and Ramírez-Andreotta, 2021).

5.5.1 Ensure procedural and participatory equity

Develop plans and actions that reflect regional priorities, especially of the most underserved and underrepresented groups, and enforce current laws that protect people and the environment. Ensure that there is translation/interpretation of resources and materials, as well as multifaceted approaches to engaging with these plans and actions, such as public transit, childcare, and timing of the meetings. Encourage landowner participation through incentives and clear guidelines for land transfers/acquisition.

5.5.2 Incentivize diverse participation

Encourage representative involvement in land use planning and cropland transition implementation, including farmers, farmworkers, local businesses, environmental groups, and Indigenous communities. Draw on the expertise and experiences of those directly affected by land use decisions to devise robust, innovative, and locally relevant solutions that enhance economic stability, preserve local traditions, and ensure environmental sustainability, fostering a sense of shared responsibility and mutual benefit.

5.5.3 Develop equitable access to land, water, and natural resources

Facilitate access to land, water, and sustainable practices for small, beginning, and disadvantaged farmers incentivizing their use of agroecological practices. Pursue the models for land ownership and management that best facilitate public benefits. Use mechanisms like green bonds, land trusts, food commons, climate resilience districts, and other cooperative mechanisms.

5.5.4 Incentivize community led, clean economic development around disadvantaged communities

Communities should be part of the decisions related to new development around them. Weight of decisions should not be tied to acreage owned; instead, each affected person should have the same voting weight. Secure public and private funding for sustainability initiatives and to reward best practices.

5.5.5 Use non-extractive practices for information exchange

Information exchange should intentionally be non-extractive with low-income and other vulnerable groups. For example, if a community is asked to provide feedback about what kind of project they want to see around their community, they should also be provided with the necessary technical assistance and funding to develop a proposal for that project. When conducting outreach to explain a project, provide a meaningful tradeoff for their time. For example, if a community suffers from poor air quality, bring indoor air purifiers for the participants. Non-extractive outreach should be properly budgeted in multibenefit cropland repurposing projects.

5.5.6 Systems thinking

Understand interconnected systems and how changes to one element of a system can create ripple effects in other systems creating unintended consequences. Systems thinking helps to identify root causes of problems and to leverage the greatest positive impacts. Land use in California can be a massive driver for change, and both policies and funding sources can help that change in positive ways.

5.6 Pursue a just clean energy transition

A clean energy transition is critical to reducing fossil fuel emissions and mitigating the impacts of climate change. This transition can have a myriad of additional environmental, public health, and local economic benefits. However, it is important to consider where the benefits and possible negative impacts of clean energy projects are being directed with the ultimate goal of improving equity and justice for vulnerable communities.

In 2018, California's SB 100 was enacted, requiring the state to supply 100% of its electric retail sales with renewable energy and zero-carbon resources by 2045. Moving forward, California's clean energy plan involves building significant new resources, particularly solar resources, in rural areas such as the San Joaquin Valley (CPUC, 2023a). If the transition occurs as a collaborative partnership with communities, industry, state agencies, and conservationists, the clean energy buildout can be beneficial to all groups. Building a diverse portfolio of clean energy resources and associated infrastructure can improve grid reliability, while creating economic opportunities for local communities (Denholm et al., 2022; Stenclik et al., 2023). California is a leader in solar development with the highest cumulative solar capacity of any state (SEIA, 2024). However, significant additional solar resources are needed to reach the state's clean energy goals, and as more land is transitioned to use for clean energy, developers and other decision-makers should be proactive in their efforts to address equity and direct benefits to the local communities hosting these projects (CPUC, 2023b).

There are many operating models for solar projects to ensure landowners and host communities can receive more direct benefits from these local clean energy projects. For example, community solar is a project design in which households subscribe to a local solar project to receive the clean energy generated by the project via credits. These projects can reduce electricity bills for participating community members. Microgrids are another solution gaining traction as they can improve grid reliability and resilience for local communities (NREL, 2020). This is particularly useful in areas where Public Safety Power Shutoffs (PSPS) are likely, as microgrids can disconnect from the main grid and continue providing power in the event of larger grid outages (Box 5).

Other mechanisms, such as community benefits agreements—binding agreements between developers and local community groups (Table 1)—can direct benefits to the local community, especially those that are not directly related to electricity supplies. These could include broader economic benefits such as workforce development programs and direct funds to the municipality, or input into the design to mitigate negative impacts from the project. In rural and farming communities, clean energy provides an option to repurpose cropland with benefits such as alternative revenue streams from land leases and net metering, or offsetting on-site electricity bills on farms.

BOX 5 Project example 5: Viejas Band microgrid in San Diego County.

Project: Viejas Microgrid **Location**: Land of the Viejas Band of the Kumeyaay Indians, CA (San Diego County)
Description: The Viejas Band of Kumeyaay Indians in southern California received a $43.3 million grant from the CEC and a $72.8 million partial loan guarantee from the Department of Energy Loan Programs Office to support a 15 MW solar and 70 MWh long-duration storage facility that will acts as a microgrid for the Tribe. The project provides significant benefits to the Tribe, including lower electricity costs, access to renewable energy, and improved resilience in the case of power shutoffs. It also supports eight permanent jobs and 250 jobs during its construction, and it aims to save more than 9,000 metric tons of CO_2. Given the significant long-duration battery storage in the project, the microgrid also supports the state's grid more broadly during times of high grid stress (DOE, 2024).

A stronger cooperative approach also addresses increasing tension between clean energy developers and local communities that can often result in delays to a project and are increasingly a barrier to the clean energy transition. Local communities should have the opportunity to engage and provide input that can meaningfully shape the development of clean energy projects to support the needs of the community. Strong perceived procedural justice is critical for gaining local support and can positively impact community perceptions of clean energy projects (Mills et al., 2019; Liu et al., 2020). Securing these positive perceptions as well as receiving direct benefits from these projects could provide traction for broader cultural acceptance of clean energy projects in key areas, such as the San Joaquin Valley, where significant clean energy development will occur.

A clean energy future is critical to addressing the impacts of climate change and supporting the growing demands on the grid. As land is repurposed to support a clean energy transition, community partnerships should be foundational in planning and implementing the transition. There should be stronger efforts to ensure that the benefits of clean energy, particularly grid reliability and affordability, are directed toward the local communities that will host clean energy projects and those that have been disproportionately harmed by the fossil fuel energy system. The collaboration between the solar industry and communities will allow for more just processes in land use decision-making and will translate to longer-term equity, public health, environmental, and economic outcomes for all.

5.6.1 Incentivize multibenefit energy solutions

Focus on incentivizing multibenefit energy solutions to optimize land use and support nearby communities, environmental efforts, and the clean energy transition. When considering land repurposing for solar projects, ecovoltaics should become the standard for new facilities to minimize the environmental impact of solar panels. Additional designs, such as agrivoltaic solar systems, should be considered for repurposing cropland.

5.6.2 Require community benefit agreements and transparency

Large clean energy projects should have binding community benefits agreements and follow a transparent flow of information between developers, and grassroots groups and residents from the beginning of the project assessment. Community benefits agreements negotiations should involve a broad representation of the community and can include stipulations such as workforce development programs, local labor requirements, local economic investments, environmental protections, and affordable housing. Any new project should ensure to do no harm to disadvantaged communities.

5.6.3 Ensure local energy security

Clean electricity generated near disadvantaged communities should be partially used to improve energy security in the region where it is generated.

5.6.4 Incentivize multiple uses of the infrastructure

Besides promoting multiple uses of the land, promoting multiple uses of the infrastructure can optimize budgets and reduce impacts. For example, ecovoltaic systems in aquifer recharge basins that create green infrastructure (a park or a sports field) near disadvantaged communities. For example, solar panels over irrigation canals can reduce evaporation in the canals while increasing the efficiency of the solar panels.

5.7 Expand skill-building, outreach, and access to information

Cropland repurposing projects should bring new educational opportunities for the regions they affect, and adequate outreach to provide information equitably and in the preferred language of the affected populations. One key solution is expanding education and training programs that are tailored to meet the unique needs of farmworkers, low-income families, and other underserved groups (for example, Ortiz-Partida et al., 2020). This includes offering language-appropriate resources, flexible scheduling, and affordable or debt-free programs (Drake, 2014; Reese et al., 2014). For example, registered apprenticeship programs that provide a living wage can help workers upskill without incurring additional financial burdens (Gallup, 2024). Providing transportation assistance and access to necessary equipment, such as laptops and specialized tools, will ensure that participants can fully engage in training opportunities without facing logistical or financial barriers.

Part of this solution consists in aligning education and training with sustainable agricultural practices and socioenvironmental justice. For instance, programs focused on cropland repurposing can contribute to climate justice by reducing water usage and promoting environmentally sustainable farming methods. These initiatives can also address broader issues of land use and resource allocation, ensuring that the communities most affected by environmental degradation and water scarcity are included in decision-making processes. By involving local leaders and integrating community-based participatory research, these programs can foster more equitable and sustainable outcomes (Balazs and Morello-Frosch, 2013).

Collaboration between educational institutions, government agencies, and nonprofits is essential to provide comprehensive support systems for participants. For example, partnerships with community colleges and agricultural organizations like the California Agricultural Teachers Association (CATA) can help integrate sustainable farming practices and climate literacy into curricula. This ensures that both current and future generations are equipped with the skills and knowledge needed to address the intertwined challenges of environmental sustainability and social justice in agriculture. By focusing on holistic education and outreach efforts that prioritize both social and environmental justice, California can move toward a more equitable future where all residents have access to the tools and knowledge necessary for sustainable livelihoods.

In addition to technical education, there is a need for leadership development within these communities to empower residents to advocate for themselves at local and state government levels. Training local leaders in grant writing, policy analysis, and community organization will equip them to drive change from within, ensuring that the solutions developed are tailored to the specific needs of their communities (Morello-Frosch et al., 2005). Such efforts can strengthen the social fabric, allowing residents to maintain a sustainable and just relationship with their environment while addressing socioeconomic inequities.

5.7.1 Provide inclusive multigenerational education for grassroots leadership and workforce development

Provide multilingual, diverse, non-extractive, and culturally appropriate approaches to education and training. Education and outreach should encompass K-16 students and adults, and it should address the questions and concerns raised by local members. Foster leadership among community members and equip them with necessary skills. Facilitate workforce development and retraining opportunities for agricultural workers.

5.7.2 Data monitoring

The transition should be monitored for accountability purposes. In particular, encourage community monitoring of baseline and new conditions of air and water quality as different land repurposing strategies are implemented. Conducting community science for open-access environmental monitoring can empower participants and give agency to communities over their own data for local advocacy purposes.

5.7.3 Ensure fair compensation

Properly compensate those participants who contribute to the success of the plans and projects, especially to ensure representation from low-income participants. This can be achieved by compensating participants for childcare, mileage, and the time spent.

6 Conclusions

The consequences from decades of chronic groundwater depletion combined with current and future climate change threats make cropland repurposing an essential climate resilience strategy for California. For cropland repurposing to effectively contribute to the state's climate resilience, socioenvironmental justice, and sustainability in agricultural regions, the ongoing and planned cropland transition needs to advance equity and center justice, particularly for frontline communities. Cropland repurposing presents a transformative, transdisciplinary approach to revitalize local economies, advance socioenvironmental justice, and recover ecological resilience while preserving the agricultural identity of the most emblematic agricultural regions of California. By developing and implementing the right policies and adhering to best practices in cropland repurposing, California can envision a future where sustainable agricultural practices coexist with thriving rural communities; ecosystem services and biodiversity are restored; there is a diversification of socioeconomic and education opportunities for underserved communities—which would also be centered in decision-making processes; and water is adequately managed as a pillar to ensure long-term sustainability.

This study presents a systems-level, coproduced Framework of best practices in cropland repurposing with an extensive literature review to facilitate socioenvironmental and economic benefits for all. This Framework demonstrates how communities and key interested actors can actively participate in scientific research by building consensus around shared objectives and challenges, and by defining best practices. This approach helps shape future decision-making in land repurposing and sets the foundation for future research that is more aligned with community priorities, sustainability, and climate resilience.

Author contributions

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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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