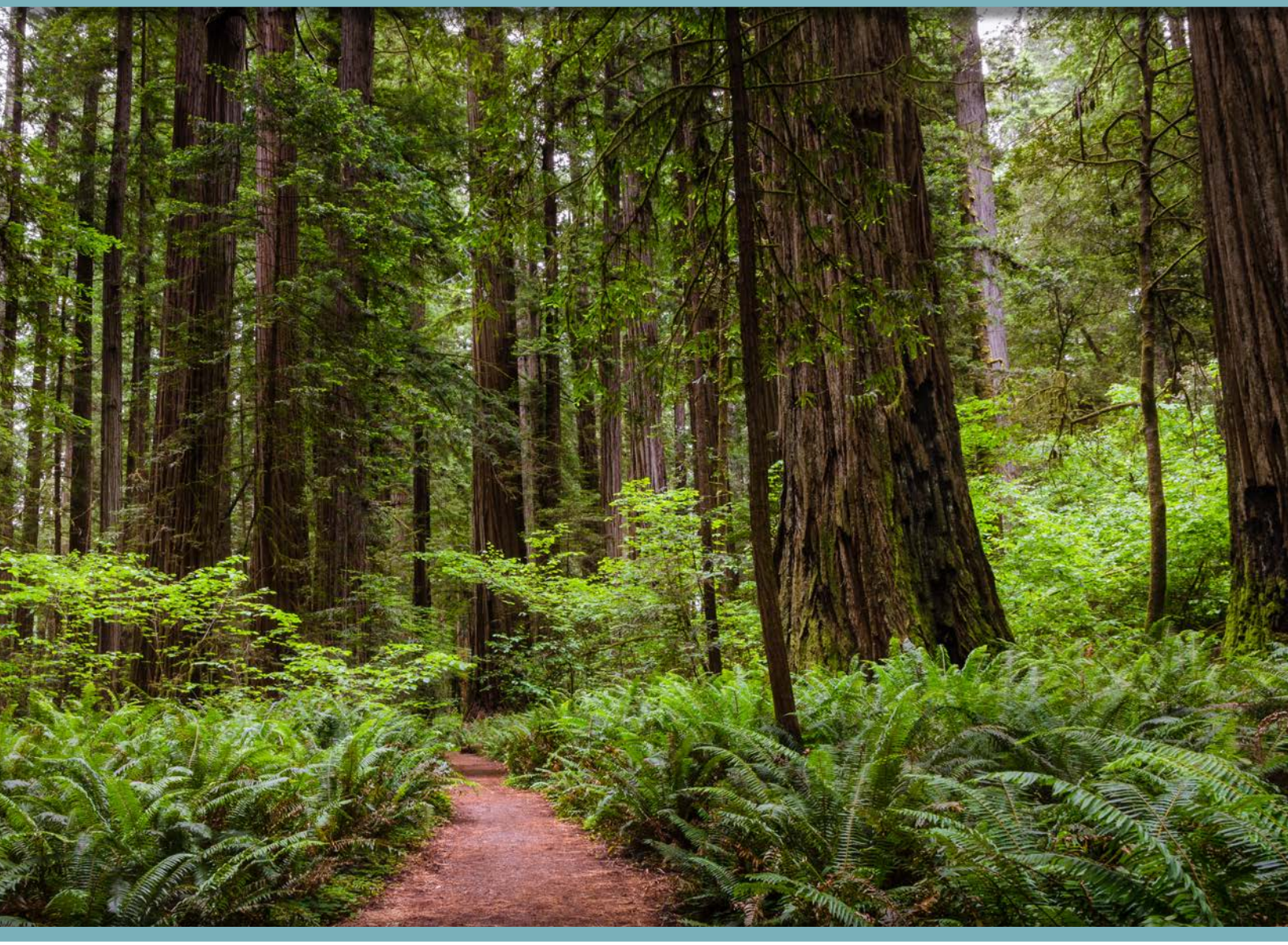
Nature-Based Climate Solutions: A Roadmap to Accelerate Action in California



The Nature Conservancy

Nature-based Climate Solutions: A Roadmap to Accelerate Action in California

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SPECIAL ACKNOWLEDGMENT

We are thankful to have joined efforts with the California-China Climate Institute during the course of writing this paper to accelerate action on climate change and nature-based strategies and address the urgency of the work needed in California and globally through partnership and collaboration.

For more information on this initiative and CCCI, please visit: https://ccci.berkeley.edu/research-nbs-tnc

BerkeleyLaw
UNIVERSITY OF CALIFORNIA
California-China Climate Institute

"Climate change is already here—and we have a shrinking window of time to avoid the most severe impacts. Nature is our solution and nature-based climate strategies can protect our communities, support our ecosystems and capture and store carbon to reduce global warming. This report identifies key policies that the State can pursue to make conservation part of business as usual and keep California resilient in a future defined by extreme climate change. Because when we protect nature, nature protects us."

Mike Sweeney, Executive Director of The Nature Conservancy, California Chapter

"To pull back from the brink of climate catastrophe, we need thoughtful, integrated climate action at all levels, including nature-based solutions. We know if we do a better job conserving and managing forests, grasslands, wetlands, farmlands, rangelands and urban green spaces in California—and around the world—we can significantly curb toxic carbon pollution. The window to act is quickly closing. There's no time to waste."

Jerry Brown, Chair, California-China Climate Institute and former Governor of California

"California policy action to support the stewardship and conservation of our lands is essential to meet our climate goals, maintain livelihoods, and protect our communities. The decisions we make today will determine if our wetlands, rangelands, farms, forests and urban green spaces become an asset or a liability in the fight against climate change. We must seize the opportunity to lead on this issue and this report helps us pioneer the way."

Robert Rivas, Assemblymember, 30th California Assembly District

Foreword

As a former local government official and legislator, and in light of the destructive, unprecedented wildfires the State is facing, the strategies outlined in this report deserve our collective attention. The Nature Conservancy (TNC) and its partners have written an instructive report on natural and working lands. It is an excellent summary of practical nature-based solutions that will help California meet its climate goals. They have identified 13 cost-effective, multi-benefit, regionally-based strategies to reduce greenhouse gas emissions and also to help communities adapt to climate change impacts.

What we need now is action! Aligning State programs, by creating partnerships across the private and public sectors of the state's economy, is an important and worthwhile goal. From reducing permitting barriers to the restoration of our wetlands, riparian corridors and forests, TNC has thoughtfully outlined hundreds of nature-based solutions. This report doesn't just focus on emission reduction strategies such as carbon sequestration, but on policies that will also help safeguard communities from impacts such as wildfires and sea level rise. Our agricultural, mountain, coastal and urban regions will benefit from many elements of this report that are directly relevant to their community priorities.

These strategies are needed to complement California's efforts in reducing vehicle emissions, reaching our 100% renewable energy goal and clean energy standards. Senate Bill 32 requires a 40% reduction of climate emissions by 2030, and we need to do more. We need an all-of-the-above strategy to avoid the most significant impacts of climate change. We will need to enhance and protect these resources in order to sustain our water and air quality, and our economy. Nature is our last line of defense in this fight.

Fran Pavley

State Assembly Member and Senator (2000-2006, 2008-2016)
Environmental Policy Director, USC Schwarzenegger Institute

Acronyms

AB Assembly Bill

CalEPA California Environmental Protection Agency

CAL FIRE California Department of Forestry and Fire Protection

CalSTA California State Transportation Agency

Caltrans California Department of Transportation

CARB California Air Resources Board

CDFA California Department of Food and Agriculture

CDFW California Department of Fish and Wildlife

CEQA California Environmental Quality Act

CNRA California Natural Resources Agency

CO_2 Carbon dioxide

CO_2e Carbon dioxide equivalent

CWA Clean Water Act

DOC California Department of Conservation

DWR Department of Water Resources

EPA U.S. Environmental Protection Agency

GGRF Greenhouse Gas Reduction Fund

GHG Greenhouse gas

MMT Million metric tons

MMT CO_2e Million metric tons of carbon dioxide equivalent

MPO Metropolitan planning organization

NCCP Natural Communities Conservation Plan

NEPA National Environmental Protection Act

N_2O Nitrous oxide

PCA Priority conservation area

RCD Regional conservation district

SB Senate Bill

SCC Social cost of carbon

SGC Strategic Growth Council

SNC Sierra Nevada Conservancy

USDA United States Department of Agriculture

VMT Vehicle miles traveled

WCB Wildlife Conservation Board

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Photo: Sevag Mehterian/TNC

Executive Summary

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This report shows how California can realize large net greenhouse gas emission reductions and multiple societal co-benefits through nature-based climate solutions. These conservation, restoration and land management strategies have great potential to address climate change but do not yet have meaningful roles in the State's formal climate strategy. The analysis presented here maps opportunities statewide for nature-based climate solutions and identifies policies and actions to support their implementation and accelerate climate action.

California's natural and working lands play an important role in the carbon cycle. Healthy vegetation and soil microbes capture and store carbon from the atmosphere in biomass and soils, while changes that disrupt or damage ecosystems—including land-use modifications, wildfires, deforestation and more—can result in stored carbon being released to the atmosphere.

The balance between carbon stored and carbon released determines whether natural and working lands function as net sources or net sinks of carbon. The nature-based climate solutions evaluated here are proven land management and conservation practices—backed by peer-reviewed science—that can make these lands function as net sinks. The analysis shows that a selection of 13 of these actions can, with strategic policies and investments, reduce cumulative net greenhouse gas emissions through 2050 by 514 million metric tons of carbon dioxide equivalent (MMT CO_2e), a major boost to California's climate efforts. Even greater emission reductions are possible: The assessment in this report accounts for only a subset of the nature-based climate solutions suitable for implementation in California.

In addition to emission reductions, nature-based solutions deliver many other benefits of value to society. These co-benefits take the form of improved public health through cleaner air and water and the availability of open space, improvements to habitat for plants and wildlife, support for keeping farmlands productive and profitable and a host of other ecosystem services, from groundwater recharge to flood risk reduction. The report maps the locations in the state where these co-benefits would be realized and identifies where they could benefit low-income and disadvantaged communities. This information can inform local and regional planning and policies to support climate action and maximize co-benefits.

California is an established leader in the policy and practice of reducing greenhouse gas emissions. The state met its 2020 goal (matching 1990 emission levels) ahead of time and is now working toward the aggressive 2030 emission-reduction target of 40% below 1990 levels, as codified in legislation, and the ambitious long-term goal of carbon neutrality by 2045, established by former Gov. Jerry Brown's 2018 executive order. To date, California's climate policies have focused primarily on reducing the many sources of greenhouse gas emissions associated with industrial sources and human activity. These measures include developing renewable energy sources; increasing efficiencies in the use of electricity and fuels in vehicles, buildings and industry; and reducing direct emissions of potent greenhouse gases such as methane.

This report presents new information showing why and how nature-based climate solutions should be added to that portfolio of strategies. Many of the policies needed to support these solutions are already in place. By combining these policies with greater coordination, technical assistance, support for partnerships and a commitment to prioritizing nature-based climate solutions, natural and working lands can become a major part of California's efforts to accelerate action on climate change.

TABLE ES-1. The 13 nature-based climate solutions for California evaluated in this report, as well as policies and strategies to support their implementation

Nature-based climate solution	Description	Statewide potential (acres)	2050 cumulative emission benefit (MMT CO_2e)	Value of avoided future damages from climate, based on the social cost of carbon	Examples of enabling policies and actions
avoided conversion	keeping natural lands intact ensures that vegetation and soils continue to sequester carbon	3.4 million	125.9	$6.52 billion	infill and redevelopment incentives; valuing ecosystem services provided by intact landscapes; support for conservation easements
urban reforestation	by planting trees in urban areas, storing carbon in above- and below-ground biomass; in addition, providing more shade	1.2 million	54.3	$2.81 billion	prioritizing State funding to focus on projects with multiple community benefits—air quality, heat islands and energy saving; expanding support for tree care and maintenance
reduced wildfire severity	through forest management practices such as thinning and prescribed fire, reducing fuel loads and limiting catastrophic wildfires	13 million	-47*	not applicable	development of local industries and markets for biomass reduction activities; support for prescribed fire through dedicated funding, policies and agency coordination
post-wildfire reforestation	by planting trees in burned areas, accelerating forest recovery and associated carbon storage	1.7 million	18	$932 million	State and federal grant programs that support post-fire restoration
changes to forest management	in commercial forests, changing management and harvest practices and schedules to increase carbon stocks in standing trees	2.6 million	162	$8.39 billion	increased landowner access to carbon markets to fund changes to forest management; combining the use of conservation easements and carbon markets
riparian restoration	by establishing trees along river and stream banks in agricultural and grassland regions, increasing carbon sequestration	380,000	4.4	$228 million	State Department of Water Resources and Wildlife Conservation Board programs that support riparian restoration
woodland restoration	by planting hardwood trees in areas where they have been lost or removed, increasing ecosystem carbon over time	1 million	-14.3*	not applicable	State Wildlife Conservation Board's grant programs to support woodland restoration

continued

Nature-based climate solution	Description	Statewide potential (acres)	2050 cumulative emission benefit (MMT CO_2e)	Value of avoided future damages from climate, based on the social cost of carbon	Examples of enabling policies and actions
agroforestry	by planting trees along agricultural field boundaries, increasing carbon stocks	600,000	24	$1.24 billion	State and federal incentive programs for agroforestry
cover cropping	by growing cover crops on annual cropland during the fallow season (winter), increasing soil carbon sequestration	1.7 million	29.7	$1.54 billion	State and federal programs that support healthy soils and conservation agriculture
compost application to grasslands	by adding compost to grasslands, increasing soil carbon sequestration and avoiding emissions from decomposing organic waste	4.8 million	46.6	$295 million	State Department of Food and Agriculture healthy soils and technical assistance programs
nitrogen fertilizer management	by using nitrogen fertilizers more efficiently, reducing both in-field emissions and emissions generated through fertilizer production	6.7 million	71.7	$3.71 billion	research and extension activities and crop management tools that support efficient fertilizer use
best practices for rice cultivation	by improving practices in rice cultivation—including mid-season drainage, alternative wetting and drying and residue removal—reducing methane and nitrous oxide emissions	520,000	19.2	$994 million	federal conservation partnership programs
wetland restoration	by restoring inland and coastal wetlands, avoiding emissions from drained soils and increasing carbon stocks	1.8 million	20.2	$1.05 billion	coordination of wetland mitigation programs, local advocacy, State and federal support programs and state and regional planning

*Implementing the reduced wildfire severity (fuels reduction) and woodland restoration strategies results in a net increase of greenhouse gas emissions over the short and medium terms (through 2050), but a net reduction by 2100.

NATURE-BASED CLIMATE SOLUTIONS

Section II of the report evaluates 13 nature-based climate solutions—actions that can be taken in our forests, cultivated lands, grasslands, wetlands and urban areas to reduce net emissions of greenhouse gases and deliver multiple co-benefits (table ES-1). Each solution represents a land management action or a conservation or agricultural practice that has been well studied, with emission reduction benefits documented in the research literature.

The spatial analysis draws on published studies and new analysis to map lands across the state that have the land cover or land-use characteristics suitable for implementing the nature-based climate solutions (fig. ES-1).

The results provide estimates of the amount and location of acreage statewide on which each of the climate solutions could be implemented—a total of nearly 30 million acres by 2050, accounting for the gradual implementation of the activities over time and for the many instances in which more than one action can be implemented on a single piece of land (see table ES-1). Estimates of the emission benefits associated with each nature-based climate solution (drawn from published studies) show the substantial climate mitigation potential of California's natural and working lands: cumulative emission benefits of 514 MMT CO_2e by 2050.

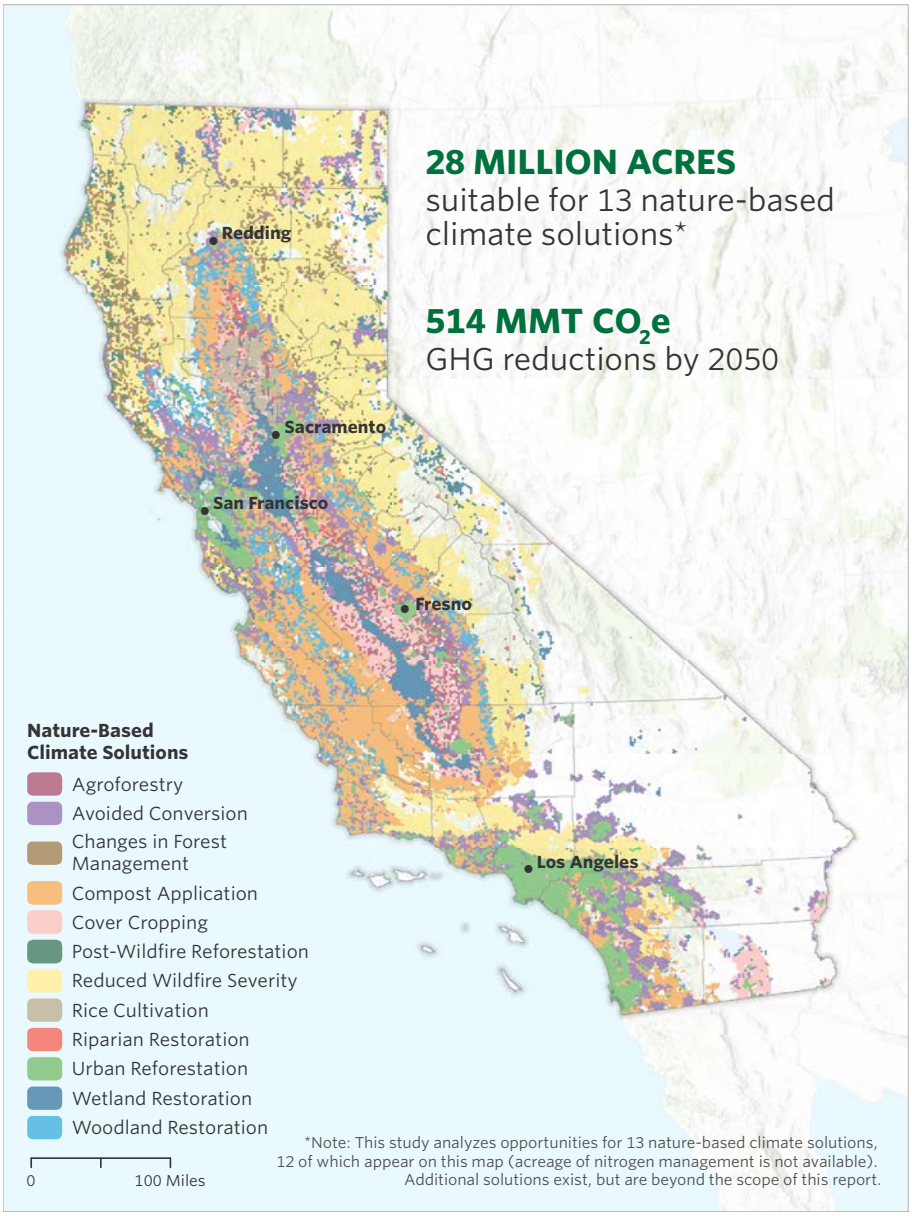


FIGURE ES-1. This statewide map illustrates greenhouse gas reduction potential and suitable acres to implement 12 nature-based climate solutions across California. As noted in the figure, while we could estimate reduction potential for nitrogen management, we were unable to map the suitable area for this report. In cases where there is solution overlap in suitable areas, the map displays the solution with the largest acreage in any location. Although the map identifies locations where nature-based climate solutions may be implemented, additional factors also will impact implementation opportunities.

Implementation cost estimates are available for some of the nature-based climate solutions and are reported in Section II of the report. In several cases, they are competitive on a per-ton basis with other opportunities for reducing greenhouse gas emissions.

Every ton of net CO_2e emission reductions helps to avoid future damages associated with climate change. To estimate a monetary value for these benefits, this analysis uses the social cost of carbon, which estimates the long-term economic costs attributable to one ton of CO_2e emitted in a given year (see Appendix C). The result: Implementing the nature-based climate solutions presented in this report over the next 30 years would avoid damages of nearly $28 billion. Note that this figure accounts only for the benefits associated with reduced greenhouse gas emissions—it does not include the monetary value of the many co-benefits associated with implementing nature-based climate solutions.

BENEFITS TO PRIORITY COMMUNITIES AND OTHER CO-BENEFITS

On top of their carbon emission benefits, each nature-based climate solution delivers additional types of societal value, or co-benefits (Section II). Such co-benefits include a wide range of public health, agricultural, ecosystem and biodiversity values.

Ensuring that actions to mitigate climate change benefit low-income and disadvantaged communities is a core priority in California's climate policy. The report identifies areas in which opportunities for developing the 13 nature-based climate solutions intersect spatially with low-income and disadvantaged communities. In these areas, the nature-based climate solutions would support improvements in environmental quality, public health and well-being (table ES-2). The report also identifies areas in which the nature-based climate solutions intersect with seven categories of benefits that deliver valuable ecosystem services.

TABLE ES-2. Co-benefits: Nature-based climate solutions benefit priority populations and provide a variety of ecosystem services

	benefits to disadvantaged and low-income communities	The State is prioritizing climate programs in disadvantaged and low-income communities, as defined in Senate Bill 535 and Assembly Bill 1550. These populations are particularly vulnerable to climate change impacts. By improving air and water quality, promoting open space, expanding urban forests and supporting ecosystem health, nature-based climate solutions will benefit these communities directly, while also helping to increase climate resilience.
	high-quality agricultural land	The California Department of Conservation has mapped high-quality agricultural acreage across the state. Nature-based climate solutions can help to conserve such lands and support continued productivity.
	connectivity	Previous studies have mapped lands that provide important links among species habitats. By conserving and restoring these lands, nature-based climate solutions protect these crucial linkages.
	groundwater recharge	By conserving and restoring natural and working lands that support groundwater recharge, nature-based climate solutions can help to replenish California's aquifers.
	habitat resilience	Resilient habitats are those likely to be stable under changing climate conditions. Nature-based climate solutions can help to conserve and restore lands identified as resilient habitat, providing critical support for biodiversity as the climate changes.
	open space	From neighborhood parks to regional, State and national parks and forestlands, publicly accessible open space supports a multitude of benefits, including improved air quality, reduced urban heat island effects, opportunities for recreation and aesthetic appeal. Implementing nature-based climate solutions can help to conserve and restore these lands.
	high-quality species habitat	High-quality habitat includes the top 10% of suitable habitat for mammals, reptiles, amphibians, birds and plants in California. Nature-based climate solutions can strengthen and protect this habitat.
	flood risk reduction	Climate change is increasing flood risk. By supporting riparian and wetland restoration and conserving natural and working lands, nature-based climate solutions can help to reduce flood risk and increase resilience to major flooding events, protecting landscapes and communities.

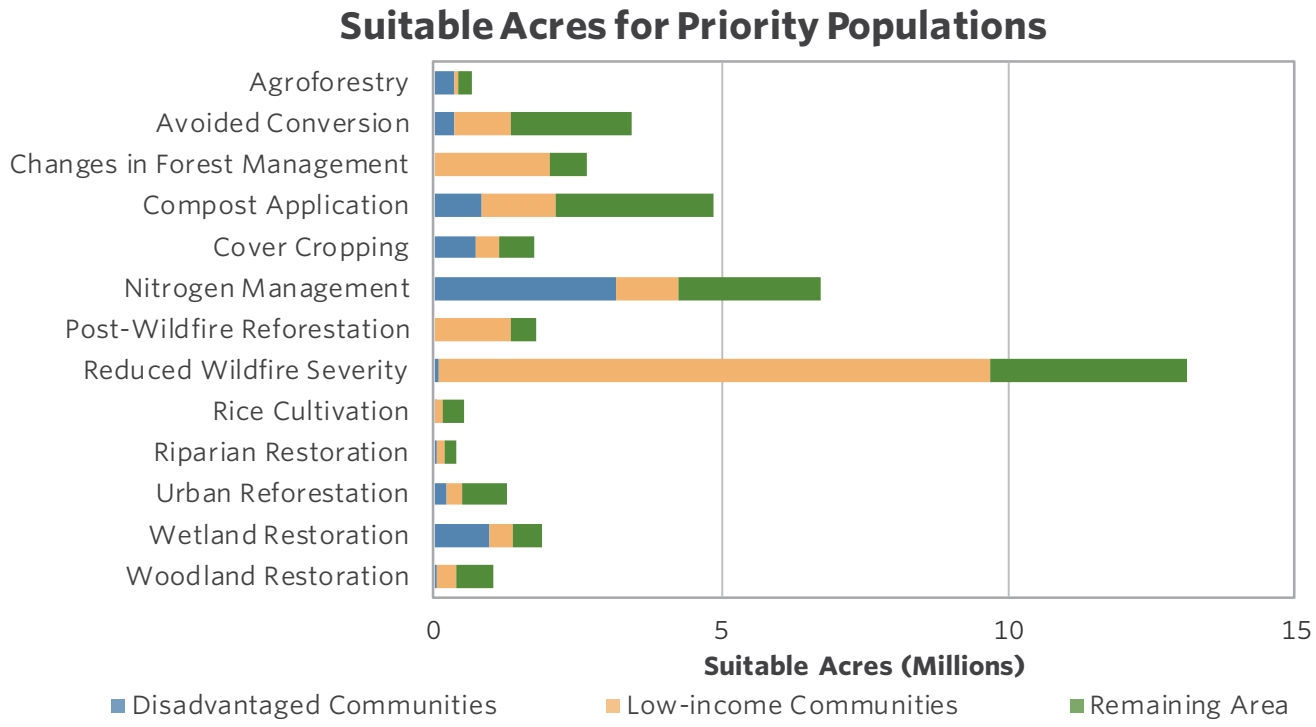


FIGURE ES-2. This chart illustrates the number of suitable acres for nature-based climate solutions that overlap with disadvantaged and low-income communities, as defined by the State—showing that nature-based climate solutions can produce meaningful social benefits in tandem with climate mitigation.

Previous work has mapped each of the co-benefit categories across the state—the locations of low-income and disadvantaged communities; lands important to habitat connectivity; areas of importance or potential importance to groundwater recharge; and so on. This analysis overlays those datasets with maps of the areas suitable for implementation of the nature-based climate solutions generated for this report.

The results show the magnitude and extent of co-benefits that can be realized through the implementation of nature-based climate solutions. For instance, figure ES-2 tallies the acreage of areas suitable for each of the 13 nature-based climate solutions that overlap with areas classified by the State as low-income and disadvantaged communities—a total of 17.5 million acres.

The spatial approach also identifies specific areas that have the potential to yield multiple types of co-benefits—areas where strategic conservation and restoration measures might yield, for instance, benefits to habitat connectivity and resilience, groundwater recharge and flood risk reduction, while also providing public benefits to disadvantaged or low-income communities. Figure ES-3 illustrates the potential impact of these multiple benefits across the state.

By spatially identifying the multiple benefits that nature-based climate solutions can provide for people and nature, the report may also be useful in prioritizing and targeting policies and conservation investments at the regional and local levels to accelerate climate action. This is illustrated in several of the regional analyses and case studies presented in Section III of the report.

REGIONAL AND LOCAL PERSPECTIVES

Section III of the report also provides closer analyses of five regions of the state—the Bay Area and Central Coast; Delta and Central Valley; North Coast; Sierra Nevada and Southern Cascades; and Southern California. These regional assessments highlight policy solutions and partnerships that can help accelerate nature-based climate action and associated benefits (fig. ES-4).

The analysis shows the potential scale of nature-based climate solutions in each of the regions (fig. ES-5). It also highlights opportunities for multiple solutions to be implemented in concert, building a portfolio of strategies to meet community, landscape and regional needs.

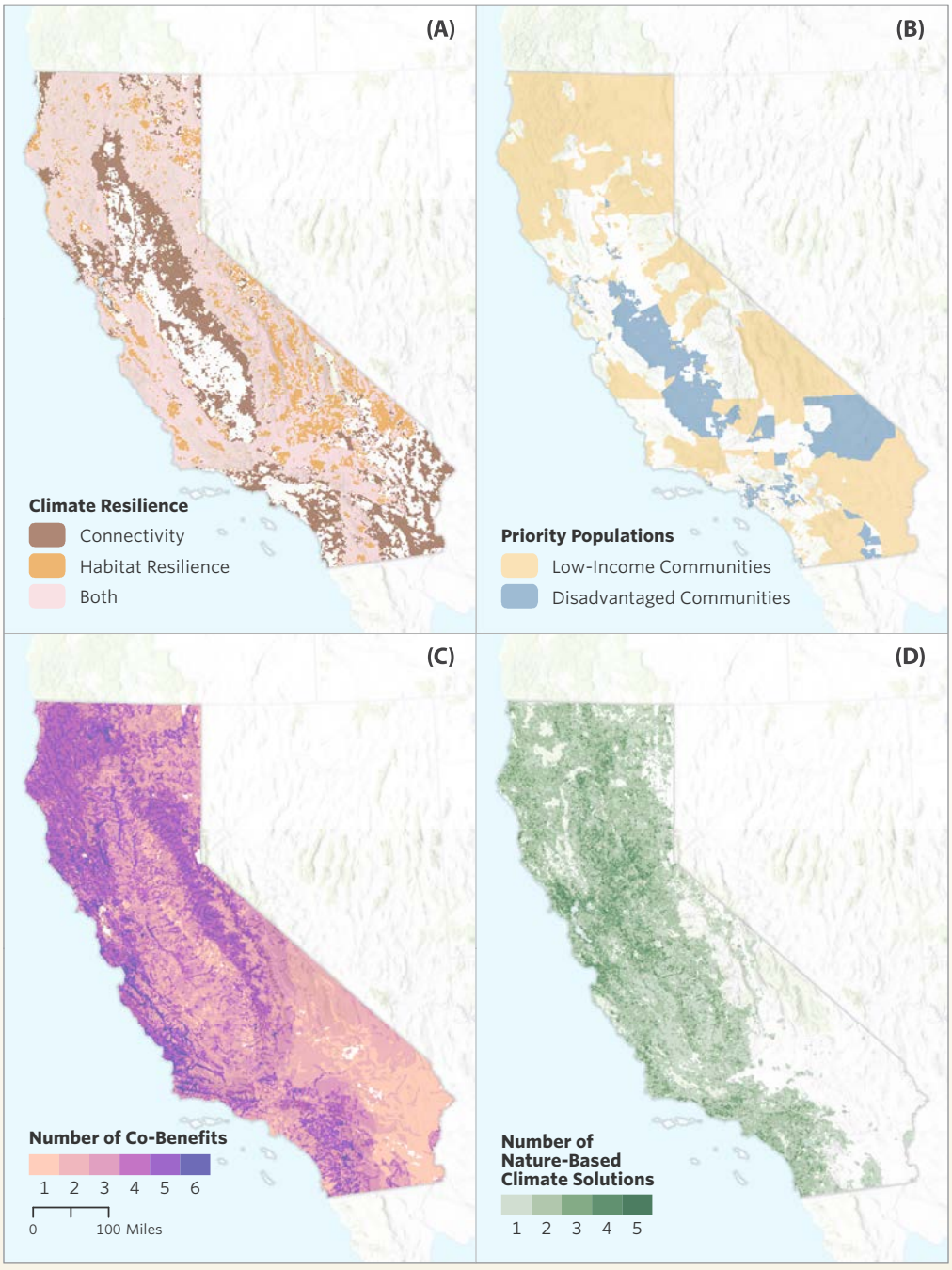


FIGURE ES-3. Nature-based climate solutions provide not only climate benefits, through the reduction of greenhouse gases, but also numerous additional benefits for people, wildlife, and nature. This four-panel figure illustrates some of these benefits. Panel (A) highlights areas where nature-based climate solutions can increase species connectivity and protect or improve species habitat. Panel (B) shows how low-income and disadvantaged communities, identified by the State as priority populations in addressing climate change, overlap with regions suitable for nature-based climate solutions. In these areas, the many environmental and social co-benefits that accompany nature-based climate solutions can help to support the communities that are often first to experience climate impacts. Panel (C) shows that these co-benefits often occur together—for example, a single nature-based climate solution might also result in increased open space, enhanced groundwater recharge and improved habitat resilience. Finally, panel (D) illustrates that many locations are suitable for more than one nature-based climate solution—with some areas suitable for implementing as many as six nature-based climate solutions together.

FIGURE ES-4. Regions of California. This report divides the state into six regions, as shown, to provide regional policy context for implementing nature-based climate solutions in California. Case studies, identified as points on this map, are used to identify policy levers and recommendations to scale up climate action with nature-based solutions.

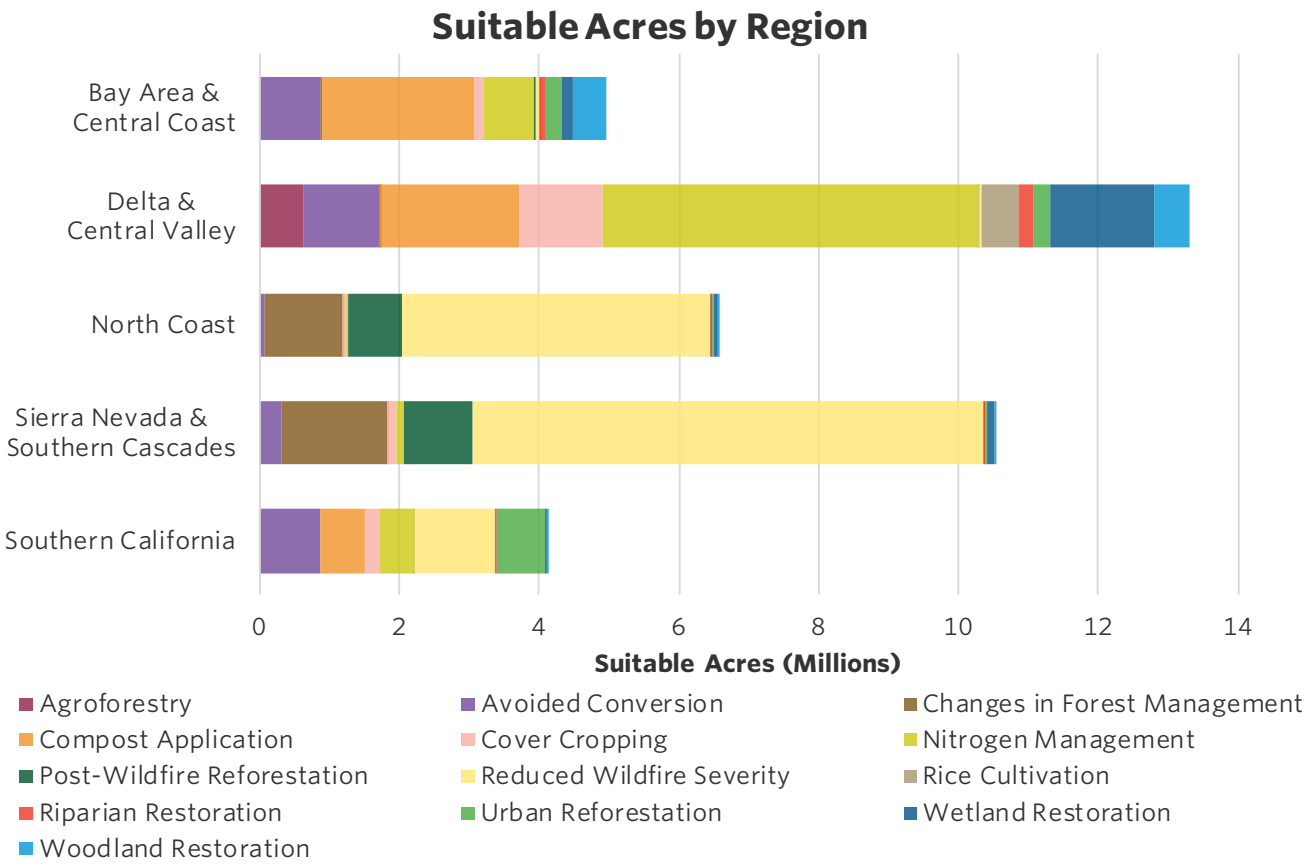


FIGURE ES-5 | SUITABLE ACRES, BY REGION, FOR NATURE-BASED SOLUTIONS. Opportunity for nature-based climate solutions across different regions in California. Opportunity is reported in terms of acres suitable for each solution within each region.

Seven case studies in this section of the report provide examples of how policies and partnerships are supporting nature-based climate solutions in every region of the state (see fig. ES-4):

- In the North Coast region, the Buckeye Forest case study illustrates an innovative combination of conservation easements and revenues from California's forest carbon market. This strategy has prevented subdivision and vineyard development on the land. It is also providing funding to support changes in forest management that will reduce net greenhouse gas emissions over time and contribute to forest health and habitat quality—while also providing for the sustainable harvest of timber.
- A case study on urban reforestation in Los Angeles demonstrates the power of partnerships. The nonprofit organization City Plants coordinates tree planting and care across the city. City Plants receives support from several State programs and works with the Los Angeles Department of Water and Power, community groups, residents, businesses and other nonprofits. Lessons include the benefits of partnering with electric utilities, opportunities to direct tree-planting funds to low-income and disadvantaged communities and the potential to maximize urban trees' multiple benefits, such as shade, stormwater runoff moderation and improved air quality.
- In the Sierra Nevada region, the 28,000-acre French Meadows Project in Placer County illustrates strategies to increase the pace and scale of fuels reduction and forest restoration work. The project brings together a wide array of partners, including the USDA Forest Service, the county's government and water agency, conservation and research organizations and private landowners. By spanning jurisdiction and ownership boundaries, the project enables a landscape-level approach to planning and implementing fuels reduction and prescribed fire activities. The case study points to several policy

priorities: facilitating forest stewardship partnerships; streamlining the permitting process for forest restoration and management activities; expanded funding for fuels reduction; and the need for public-private partnerships to develop markets for woody biomass, including small-scale renewable energy generation.

These case studies—and the four others presented in Section III—show the importance of a multidimensional approach, combining policy measures and incentive programs, good science and collaborations among landowners, agencies, local governments and nongovernmental organizations.

POLICY IMPLICATIONS

Without policy and funding support for expanded stewardship, conservation and restoration of its lands, California risks falling short of its collective goals to address climate change—and misses critical opportunities to secure other important benefits for people and nature. Key strategies to support California in accelerating action include

- identifying and concisely communicating short-, medium- and long-term climate goals for California's natural and working lands, including specific goals for disadvantaged and low-income communities
- elevating natural and working lands (and their climate benefits) across State grant programs, including those that are not typically focused on natural resources, such as health, transportation, housing and other land-use planning programs
- reducing permitting and agency coordination barriers to the implementation of natural resource strategies such as wetland restoration and fire risk reduction
- advancing greater funding coordination across local, State and federal governments and private entities
- aligning State programs and their guidelines to account consistently for the climate benefits of natural and working lands and the climate impacts associated with their loss
- accelerating outreach, providing technical support and using existing tools, universities and University of California Cooperative Extension specialists to build capacity to assess the climate benefits of natural and working lands
- including more experts in ecology, ecosystem and climate health and land use in government decision-making bodies (boards, committees, oversight groups and so on)
- expanding public outreach and education regarding the connections between the climate benefits of natural and working lands and healthy food, community safety and public health

If California capitalizes on the many opportunities for nature-based climate solutions detailed in this report, the state's natural and working lands can play a leading role in accelerating the reduction of net greenhouse gas emissions—while supporting community and ecosystem health and continuing the State's legacy of climate action innovation and leadership.

Photo: Bridget Besaw

I. Introduction

The climate is changing, and California's diverse and iconic landscapes face multiple threats as global temperatures continue to rise. Already, impacts of climate change—including extreme heat events, intense droughts and rising sea levels—are being observed throughout the state. Habitat loss, the proliferation of invasive species, the pace and scale of land conversion and, increasingly, catastrophic wildfires all indicate that California's ecosystems are under stress.

The State of California has emerged as a global leader in taking action to reduce the greenhouse gases (GHGs) and other emissions that hasten climate change. As the timeline in figure 1 indicates, California's climate policies have largely focused on mitigation, or reductions in greenhouse gas emissions. More recently, policies have also focused on adaptation, or preparing for the inevitable impacts of climate change on our built and human systems. From California's first sweeping climate legislation in 2006—the California Global Warming Solutions Act—to the State's 2045 goal for carbon neutrality, the hallmarks of California's policies have been innovation, bipartisanship and comprehensive action.

The State has been lauded for its climate successes—which include reaching its 2020 climate target early—but current estimates indicate that California is far from on track in meeting its future climate targets. Recent studies, including one by the nonprofit organization Next 10, suggest that California must cut emissions nearly twice as quickly in the next decades as it did in the previous one if it is to meet its future climate targets (Perry et al. 2019; Marvin et al. 2018). Figure 2 illustrates the deep reductions in GHG emissions that are needed for California to achieve its climate goals: As the yellow-shaded region shows, substantial reductions are needed to meet the 2030 and 2050 climate goals, and even bolder action—shown by the lower, green-shaded region—will be needed to transition to carbon neutrality, or net zero emissions, by 2045.

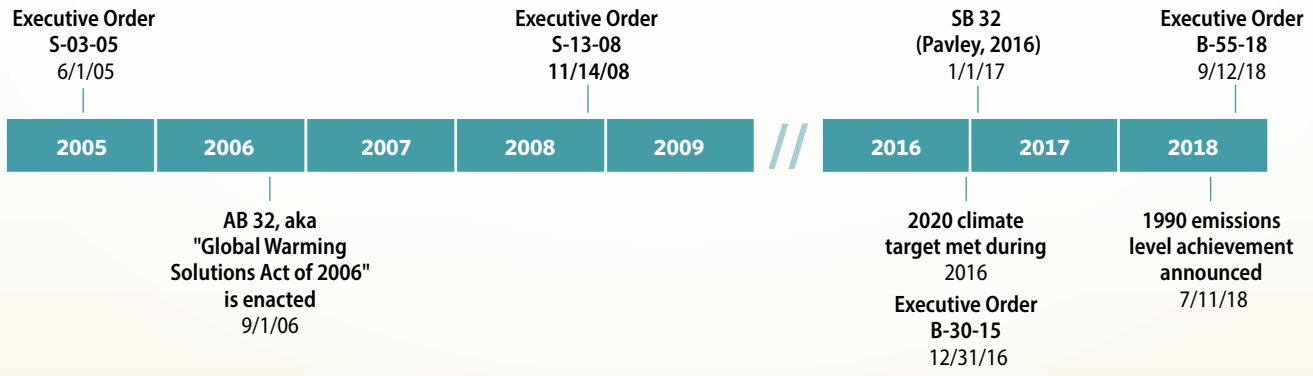


FIGURE 1. Timeline of climate action in California. California has a legacy of leadership in addressing climate change. This figure highlights key policy actions and goals that characterize the State's approach to mitigating greenhouse gases and strengthening the resilience of California's communities in the face of unavoidable impacts.

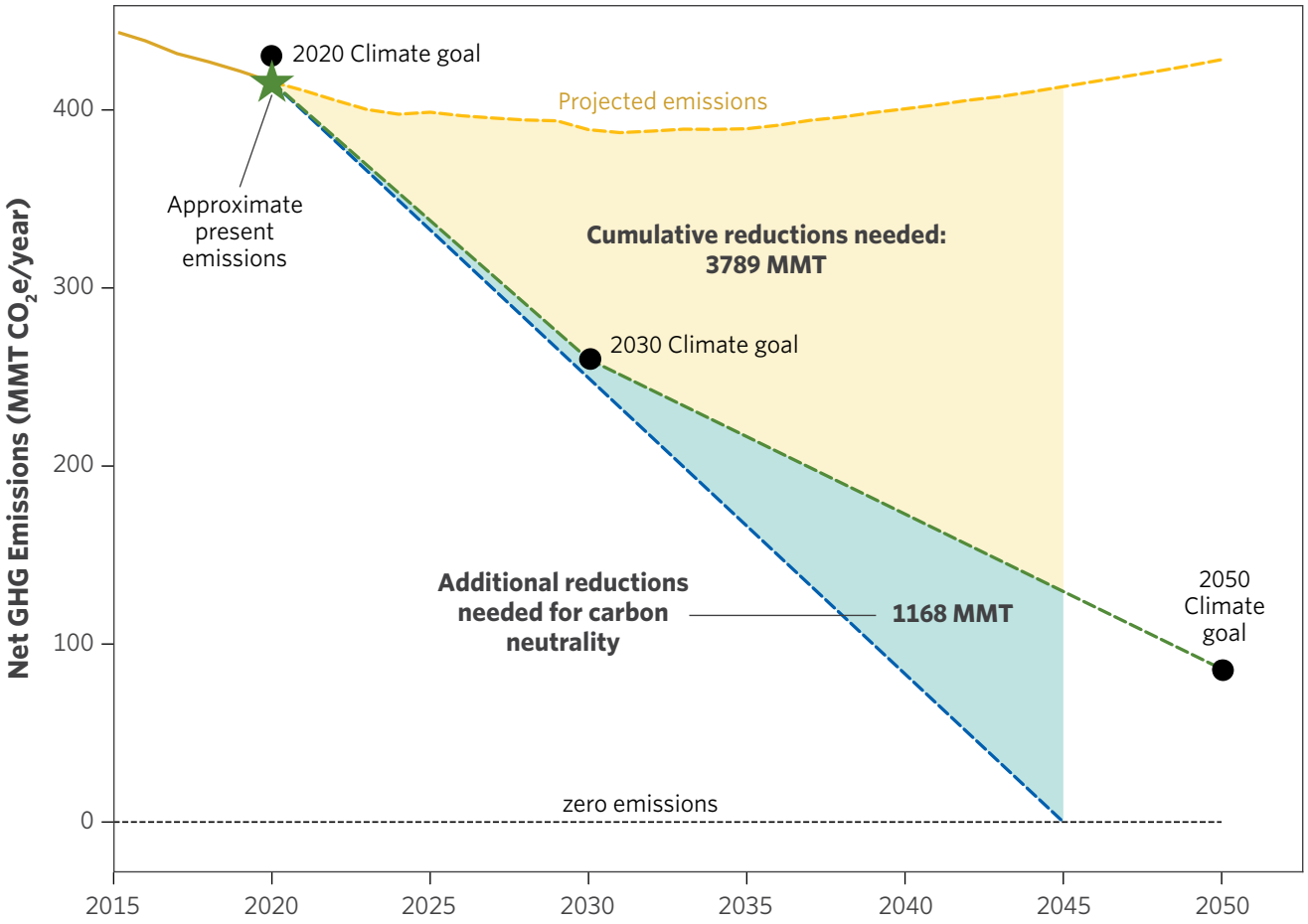


FIGURE 2. GHG reductions needed to avoid most damaging climate impacts. Without California's 2020, 2030 and 2050 climate goals, greenhouse gas emissions would likely remain steady through 2050 (California Air Resources Board). The State's 2030 and 2050 climate goals can be achieved through steady greenhouse gas reductions, shown by the top, yellow-shaded area, with estimated cumulative reductions of 3,789 MMT CO_2e. However, even these reductions fall short of carbon neutrality, or zero emissions. Additional, deeper reductions, shown by the darker-shaded region, are needed to achieve carbon neutrality by 2045. The cumulative value of these additional reductions is estimated to be 1,168 MMT CO_2e. The nature-based policy opportunities discussed in this report can help California achieve these deeper emission reductions.

Carbon neutrality, while an ambitious goal, is critical for California. A recent report by the Intergovernmental Panel on Climate Change (IPCC), the world's leading body for assessing the science on climate change, suggests that global emission levels need to approach net zero by midcentury to prevent the most destructive impacts of climate change (IPCC 2018). California's 2030 and 2050 climate goals put the state on a path toward carbon neutrality—but efforts must be accelerated to reach net zero by midcentury.

While California has developed inventories, drafted plans and made relatively modest investments in natural and working lands to address climate change, a deeper sense of urgency and commitment is needed to ensure that these resources can provide critical climate benefits and support a carbon-neutral future.

THE FUTURE OF CALIFORNIA'S LANDS IN THE ABSENCE OF INCREASED ACTION

California's natural and working lands—its forests, grasslands, wetlands, farmlands, rangeland and urban green spaces—cover more than 90% of the state (Baker et al. 2019).[1] These lands provide Californians with a multitude of benefits: They serve as a source of food and fiber,

store and transport water, provide habitat for wildlife, house renewable energy projects, support recreation and local economies and enhance the resilience of communities in the face of extreme climate events.

California's lands, and the ecosystems they support, also play an important role in the carbon cycle. Growing vegetation captures and stores carbon from the atmosphere, while changes that impact ecosystems—including land-use modifications, wildfires, deforestation and more—can result in the release of stored carbon to the atmosphere. The interplay between carbon stored and carbon released determines whether our lands function as a net source or a net sink of carbon. Historically, they have functioned as robust net sinks of carbon dioxide (CO_2) (IPCC 2013).

Data from recent analyses suggest that, in some cases, California's natural and working lands currently lose more carbon than they sequester (CARB 2018; Gonzalez et al. 2015). Continued extreme heat events, droughts, floods, wildfires, development and other anthropogenic impacts are likely to continue driving these losses. Without direct and specific intervention, California's natural and working lands will likely become an increasing net source of emissions instead of a sink, exacerbating—rather than slowing—climate change (fig. 3). Given the deep reductions needed to reach carbon neutrality and prevent the most catastrophic climate impacts from occurring, California cannot afford to ignore the role of its natural and working lands in addressing climate change.

Fortunately, conservation and land management activities can influence our lands' ability to remove and store carbon.[2] With swift policy action and investment, California can ensure that its natural and working lands reduce emissions and continue to provide communities with essential benefits.[3]

PURPOSE AND SCOPE OF REPORT

California's successes in reducing GHG emissions come from years of considered interventions in the built environment. Energy efficiency and conservation gains, as well as the development of renewable energy, have improved CO_2-related performance across industrial facilities, water conveyance, farm irrigation and pumping systems, electric vehicles and residential and commercial buildings. The most recent California Climate Change Scoping Plan includes comprehensive lists of potential pathways to continue these improvements and help the State to reach its ambitious 2030 climate targets (CARB 2017). The upcoming Scoping Plan will likely include even greater ambition by introducing a plan for the State to reach carbon neutrality by midcentury. This report assumes continued advancement in State efforts to reduce emissions in the built environment.

As acknowledged in the Draft California 2030 Natural and Working Lands Climate Change Implementation Plan (CARB 2019b), the conservation, restoration and stewardship of natural and working lands are critical for achieving carbon neutrality. Proven and reliable efforts to sequester carbon currently exist only on natural and working lands. Additional interventions on natural and working lands—well beyond those detailed in this

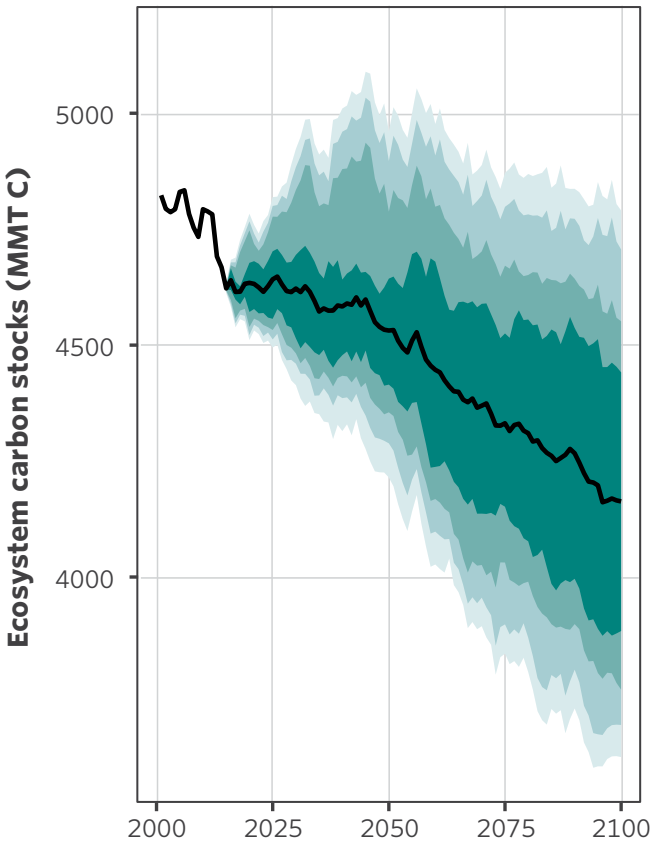


FIGURE 3. Predicted carbon stock trends for California. Without intervention, California's natural and working lands are projected to lose carbon over the next several decades. This figure, reproduced with permission from Sleeter et al. (2019), illustrates projected changes in carbon stocks—including dead organic matter, live biomass and soil—out to the year 2100. As noted by Sleeter et al., the magnitude of decline in ecosystem carbon is highly uncertain (green-shaded areas), but suggests a net loss in ecosystem carbon out to 2100 (mean, or black line).

report—will also inevitably emerge as the State focuses on this area of work.

Leveraging the GHG reduction potential of California's natural and working lands requires investment in policies and strategies that protect existing carbon stocks and increase carbon sequestration. Nature-based climate mitigation strategies (or nature-based climate solutions[4])—activities rooted in conservation, restoration and improved land management—are increasingly being recognized for their potential to perform these services while providing additional social, environmental and economic benefits.

At the time of this report, no legislation, orders or plans have addressed comprehensive, cross-sectoral climate action that includes natural and working lands, that is intended to reduce emissions and spur carbon sequestration and that will help drive net emissions to zero. In California, the inclusion of natural and working lands in climate change policy has largely been limited to California's GHG cap-and-trade program (CARB 2020). Though this program has helped to catalyze climate action in the forest sector through offsets, and though auction proceeds have been invested in other nature-based climate solutions, more robust policies and actions are critically needed so natural and working lands can be conserved at an accelerated pace and scale—and so California can take advantage of the climate benefits, and associated co-benefits, that such conservation efforts can provide.

This report highlights the necessary actions. It illustrates the significant contribution that nature-based climate solutions can and should make toward California's climate goals and identifies the related policies and incentives that could support carbon neutrality. It also highlights these policy recommendations in a spatially explicit manner so that policymakers can gain a deeper understanding of the ways in which State policies, and in some cases local policies, can support nature-based climate actions in their own regions.

ORGANIZATION

The sections that follow spatially identify practices and policy pathways to implement nature-based climate solutions in California. Section II highlights 13 nature-based climate solutions across the state (table 1), identifies geographical areas where the studied solutions

TABLE 1. Nature-based climate solutions analyzed in report

Natured-based climate solution	Description
avoided conversion	reducing rates of land conversion for anthropogenic uses to avoid carbon emissions
urban reforestation	planting trees in urban areas to increase tree canopy cover and provide carbon sequestration in above- and belowground biomass
reduced wildfire severity	using forest management practices such as thinning and prescribed burns to reduce fuel loading in forests
post-wildfire reforestation	planting trees in areas that have burned under high-severity wildfires to improve carbon stocks*
changes in forest management	changing forest management practices to increase carbon stocks and reduce harvest volumes
riparian restoration	establishing forest cover along riverbanks and stream banks in agricultural and grassland regions for soil carbon benefit
woodland restoration	planting hardwood trees in areas where they have been lost or removed to improve carbon storage in soil
agroforestry	planting trees and hedgerows along agricultural field boundaries to provide windbreaks and increase soil carbon sequestration
cover cropping	rotating nonmarketable crops in the fallow season between main crops to improve soil carbon sequestration
compost application	adding compost to grasslands to increase soil carbon sequestration
nitrogen management	using nitrogen fertilizers more efficiently to reduce in-field and upstream emissions
rice cultivation	improving practices in rice cultivation—including midseason drainage, alternate wetting and drying and residue removal—to reduce methane and nitrous oxide emission
wetland restoration	restoring wetlands to avoid emissions from drained soils and increase carbon stocks

*This report's definition of post-wildfire restoration is based on conifer forests in certain regions characterized by wildfire.

TABLE 2. Co-benefits identified in analysis

Co-benefit		Description and connection to nature-based climate solutions (NBS)
	disadvantaged and low-income communities	Disadvantaged and low-income communities, defined according to SB 535 (De Leon, Chapter 830, Statutes of 2012) and AB 1550 (Gomez, Chapter 369, Statutes of 2016), have been identified as priority populations for State climate investments. These populations are particularly vulnerable to climate change impacts.
	high-quality agricultural land	High-quality agricultural land includes prime farmland, unique farmland and farmland of statewide or local importance. Nature-based climate solutions implemented on agricultural land, like cover cropping and agroforestry, can also lead to increased crop yields.
	connectivity	The term *climate connectivity* denotes linkages that connect species habitats. Nature-based climate solutions can restore or protect crucial linkages that facilitate species movement.
	flood risk reduction	Nature-based climate solutions can reduce flood risk and increase resilience in unavoidable flooding events, protecting both landscapes and communities.
	groundwater recharge	Groundwater recharge includes both modeled recharge in natural lands across the state and groundwater recharge on agricultural lands. Nature-based climate solutions enhance groundwater recharge and can help in replenishing drained aquifers.
	habitat resilience	Habitat that remains stable under changing climate conditions is often referred to as *resilient habitat*. Nature-based climate solutions can help to maintain resilient habitats, providing critical support for biodiversity as the climate changes.
	open space	Publicly accessible and undeveloped green space provides a multitude of health and social benefits including improved air quality, reduced urban heat island effects, opportunities for recreation and aesthetic appeal. Implementing nature-based climate solutions can increase public open spaces across the state, ultimately improving public health.
	high-quality species habitat	High-quality habitat includes the top 10% of suitable habitat for mammals, reptiles, amphibians, birds and plants in California. Nature-based climate solutions can strengthen and protect this habitat.

might be implemented and describes co-benefits, costs and State policies that can spur action. Section III takes a more granular look, using regional and local case studies to focus on policy pathways to action—while also highlighting opportunities to scale up action more broadly. The report concludes with high-level recommendations.

Appendices A-C provide supplementary information. Appendix A tabulates useful federal, State and local resources related to the policy pathways discussed throughout the report. Appendix B describes methods used to map GHG reduction estimates and geographic suitability for the nature-based climate solutions described in this report, which are based on studies by Marvin et al. (2018), Fargione et al. (2018) and Cameron et al. (2017). Appendix C details methods used to estimate costs associated with the 13 nature-based climate solutions.

To provide additional context throughout the report, co-benefits are identified in line with nature-based solutions and policies. These co-benefits are grouped into the categories shown in table 2. Additionally, disadvantaged and low-income communities are spatially identified where possible, along with nature-based climate solutions to help guide and prioritize action toward the communities that often are first to experience devastating climate impacts.[5]

Photo: Alex Snyder/TNC

II. Nature-based Climate Benefits and Related Policies: A Statewide Look

Natural and working lands are the only sector, or climate solution, in which emission reductions, adaptation actions and sequestration efforts coalesce. One action can produce all three of these outcomes. For example, planting cover crops reduces emissions by reducing the need for tillage; the cover crops sequester carbon by keeping more carbon in plant roots and in deep-soil storage; and cover crops aid in adaptation by increasing soil water holding capacity, reducing flood risk and topsoil runoff. Other benefits include supporting higher crop yields, which makes locally grown food more available, and contributing to native habitats and biodiverse communities (Hartwig and Ammon 2002).

Natural and working lands are also where Californians turn for comfort, exercise, fresh and healthy food, adventure, safety and rejuvenation. California is rich with native species, wild places, urban parks, productive farms, deserts, coastlines, ancient forests, green alleyways and school gardens. Preserving, enhancing and expanding these natural spaces will allow the state to thrive in times of crisis and calm, connecting all of us to the iconic and fruitful landscapes we know and need.

Individually and collectively, nature-based climate solutions can ensure access to local food, safeguard communities from floods, fires and other inevitable climate risks and increase Californians' abilities to experience the state's majestic and diverse natural resources, among other benefits. With strategic policy implementation that includes nature across the state, California can prevail in its efforts to reach carbon neutrality, lead national and international innovative climate action and protect urban, suburban and rural communities alike.

The purpose of this section is not only to highlight the GHG reduction potential and associated benefits of key nature-based climate mitigation solutions but also to identify the broad range of policies that could support these benefits across the state. In some cases, we highlight solutions that individually, in the shorter term, have little to no GHG reduction benefit—but are still worth pursuing because GHG reduction benefits accrue over the longer term and because these solutions result in other critical public benefits. When aggregated, nature-based mitigation solutions offer significant opportunities for GHG reduction.

STATEWIDE SUMMARY

The maps shown in this section illustrate, on a statewide basis, the tremendous potential of California's natural and working lands to achieve climate benefits—along with additional benefits for nature and people—over a 30-year time horizon. Figure 4A shows areas of greatest opportunity for nature-based climate solutions across the state, expressed in terms of suitable acres per county. Collectively, the nature-based solutions analyzed in this report can, implemented on more than 28 million acres of land that effectively span the state, provide net emission reductions of up to 514 million metric tons of carbon dioxide equivalent (MMT CO_2e) by 2050.6 These reduction estimates are based on the results of three studies (Marvin et al. 2018; Fargione et al. 2018; Cameron et al. 2017) that collectively probe how the implementation of nature-based climate solutions results in changes in carbon stocks. It is worth noting that eight of the solutions mapped in this report are also spatially presented by Marvin et al., using a different approach. Appendix B provides clarifying information on the differences between methods used.

As figures 4B, 4C, 4D and 4E indicate, nature-based climate solutions provide substantial benefits beyond

OVERVIEW OF POTENTIAL REDUCTIONS, SUITABILITY AND BENEFITS

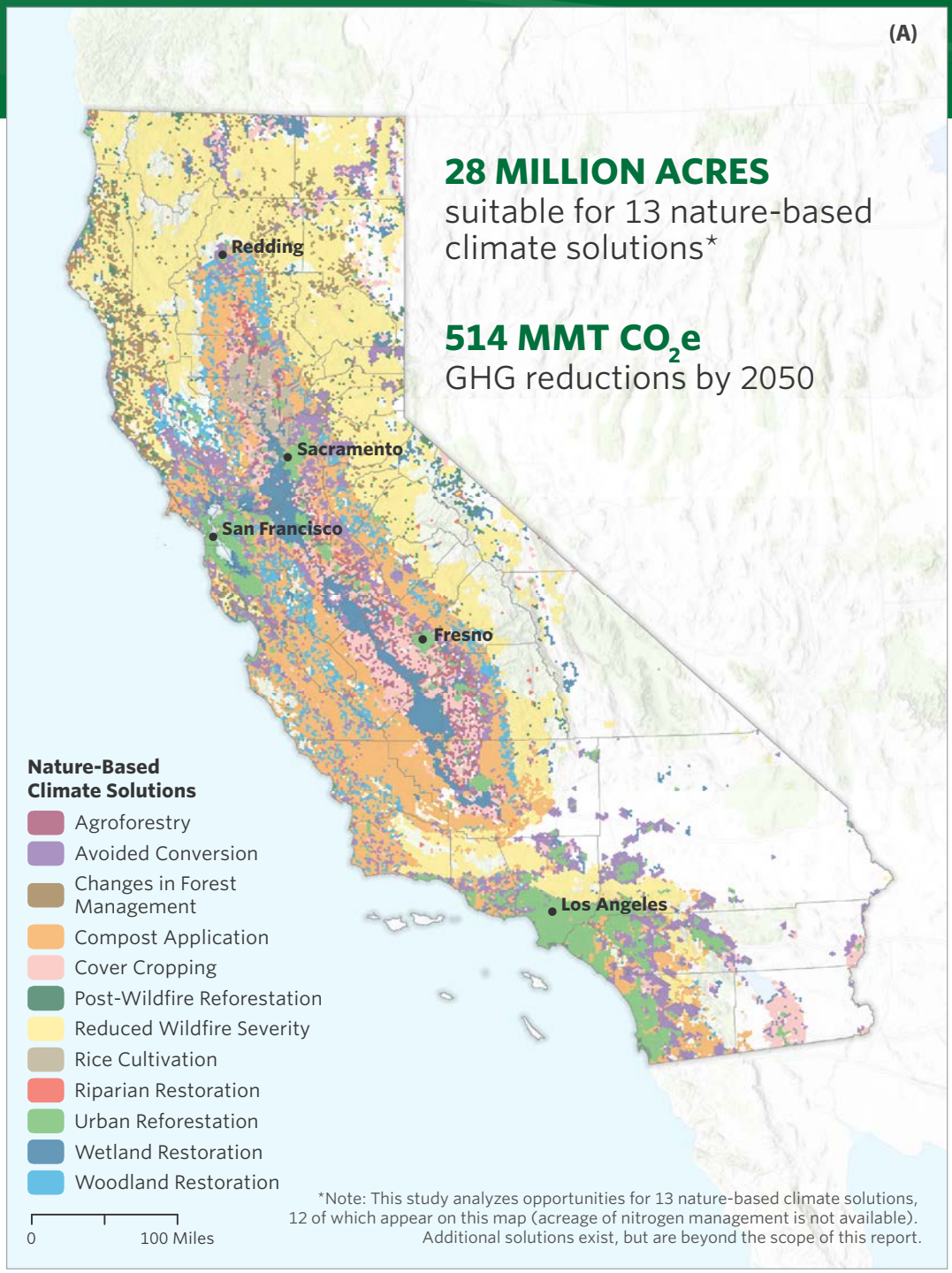


FIGURE 4A. This statewide map illustrates greenhouse gas reduction potential and suitable acres to implement 12 nature-based climate solutions across California. As noted in the figure, while we could estimate reduction potential for nitrogen management, we were unable to map the suitable area for this report. In cases where there is solution overlap in suitable areas, the map displays the solution with the largest acreage in any location. Although the map identifies locations where nature-based climate solutions may be implemented, additional factors also will impact implementation opportunities.

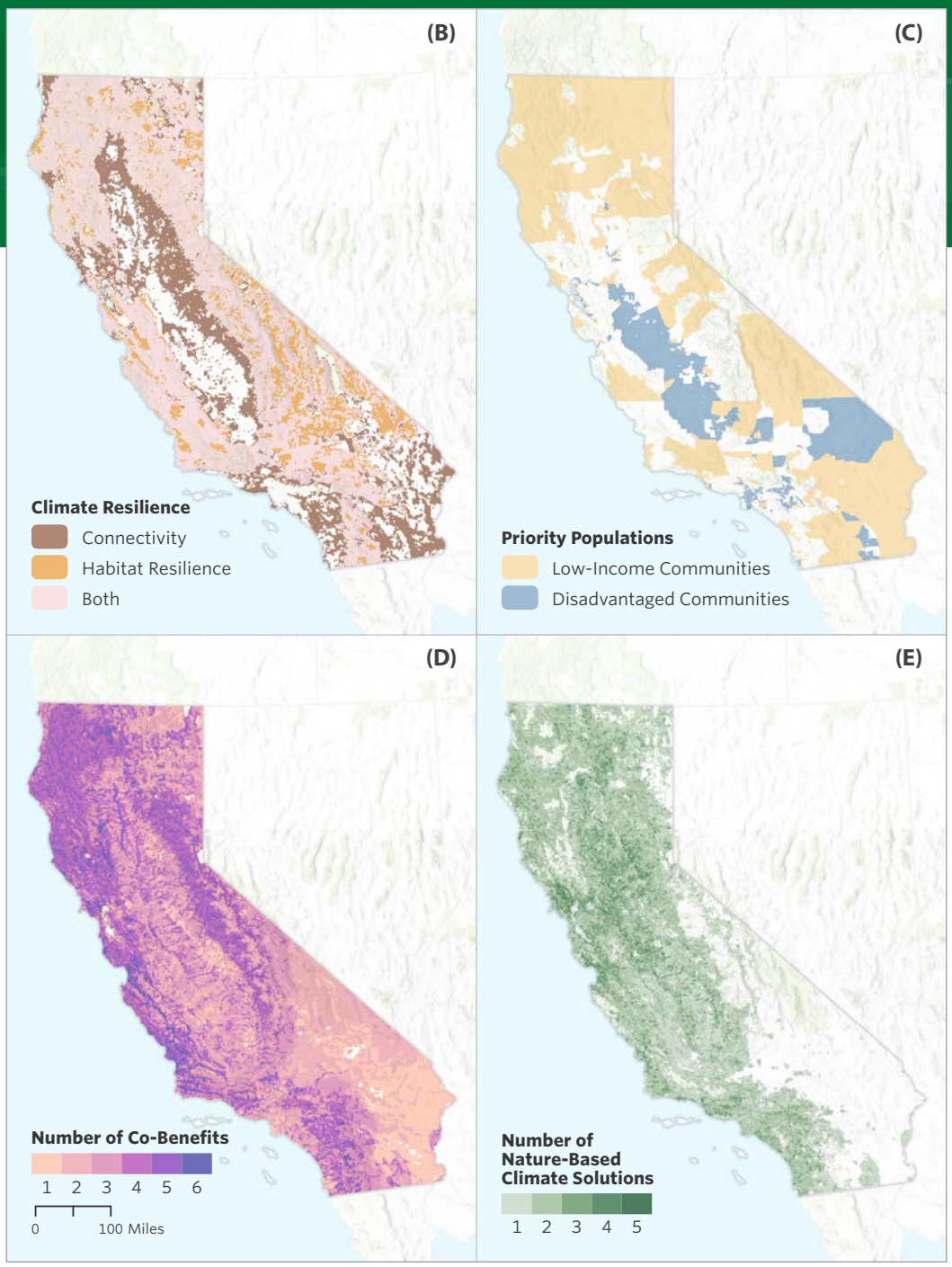


FIGURE 4 B, C, D, AND E. Nature-based climate solutions provide not only climate benefits, through the reduction of greenhouse gases, but also numerous additional benefits for people, wildlife, and nature. This four-panel figure illustrates some of these benefits. Panel (B) highlights areas where nature-based climate solutions can increase species connectivity and protect or improve species habitat. Panel (C) shows how low-income and disadvantaged communities, identified by the State as priority populations in addressing climate change, overlap with regions suitable for nature-based climate solutions. In these areas, the many environmental and social co-benefits that accompany nature-based climate solutions can help to support the communities that are often first to experience climate impacts. Panel (D) shows that these co-benefits often occur together—for example, a single nature-based climate solution might also result in increased open space, enhanced groundwater recharge and improved habitat resilience. Finally, panel (E) illustrates that many locations are suitable for more than one nature-based climate solution—with some areas suitable for implementing as many as six nature-based climate solutions together.

the mitigation of climate change. They serve to fortify California's ecosystems against climate impacts by increasing landscape connectivity and providing support for vital habitat (fig. 4B). Areas of opportunity overlap substantially with priority populations in the state, underscoring the social significance of actions that carry multiple co-benefits (fig. 4C). The co-benefits mapped in figure 4 aggregate in regions where there is opportunity to implement nature-based climate solutions (fig. 4D). In a similar vein, many of the nature-based solutions mapped in figure 4 overlap—a feature reflected in figure 4E. In many cases, multiple nature-based solutions can be implemented within a single acre of land; 25 million acres are available for at least one of the 13 solutions considered in this report, and 4.7 million acres are available for more than one solution. These acres do not include 6.7 million acres of cropland where nitrogen management can be implemented, due to limitations in available data (see Appendix B for details).

Achieving climate benefits and co-benefits across the state requires the use of approaches that can transcend jurisdictional boundaries and land types, though these features may influence which policies are most optimal in different regions. Figure 5 illustrates the patchwork of land ownership across California and calls attention to the role that forest activities alone can play in mitigating climate change.

Across California, the potential for reductions in GHG emissions varies by individual solution. As shown in figure 6, the potential for reductions ranges from -47 MMT CO_2e by 2050 for reduced wildfire severity to 162 MMT CO_2e by 2050 for changes in forest management. Negative reduction values—such as occur for reduced wildfire severity and woodland restoration—represent an increase in emissions. But though the implementation of reduced wildfire severity and woodland restoration may result in near-term emissions, these solutions will provide net reductions in emissions over longer time scales. Extending the time horizon for implementation from 2050 to 2100 results in net GHG reductions for both reduced wildfire severity and woodland restoration. The time windows that accompany interventions like reduced wildfire severity stress the need to take proactive action now. Moreover, these interventions overlap significantly with disadvantaged and low-income communities (fig. 7)—where co-benefits can immediately avail the public, independent of mitigation potential.

In the subsections that follow, these nature-based solutions are mapped on an individual basis and analyzed according to the roles that they play in achieving climate benefits on California's natural and working lands. To provide economic context, each solution that provides climate mitigation benefits by 2050 includes an assessment of the resultant savings from emissions reduced—captured by the social cost of carbon. Where economic costs were readily available, these solutions also include an estimate of the cost per metric ton of CO_2e reduced. The result is a social cost of carbon for all solutions except reduced wildfire severity and woodland restoration (which don't provide net climate benefits until after 2050) and a cost per metric ton for avoided conversion, post-wildfire reforestoration, changes in forest management, riparian restoration and cover cropping.[7]

Finally, a suite of policies is identified that could help achieve GHG reduction goals and also provide complementary benefits.[8]

MAINTAINING CALIFORNIA'S NATURAL AND WORKING LANDS

California's efforts at avoiding conversion of natural and agricultural lands, supporting infill development and preserving intact landscapes have waxed and waned over many decades. Policies that support or monetize conversion avoidance have included redevelopment funding and programs at the local level, the Land Conservation Act (or Williamson Act), the Sustainable Agricultural Lands Conservation Program and conservation plans (for example, Habitat Conservation Plans). Additionally, project-specific mitigation efforts at all levels of government can aid in avoided conversion outcomes by requiring conservation, restoration and preservation of landscapes similar to those being converted for land-use projects.

A number of California's issue-specific plans and laws address avoided conversion.[9] For example, the Climate Change Scoping Plan targets a reduction in per capita emissions as an important path to reducing statewide GHG emissions, with an emphasis on per capita vehicle miles traveled (VMT). The Sustainable Communities and Climate Protection Act of 2008 (or SB 375) required the California Air Resources Board (CARB) to set regional targets for GHG emission reductions, yet a review of the impact of the policy 10 years later showed that the State is not on track to realize regionalized GHG reduction goals. CARB determined that VMT per capita is now higher than it was at the passage of SB 375 (CARB 2018).

FIGURE 5. Land ownership varies across California, as shown by this map. Forest-based solutions—including changes in forest management, post-wildfire reforestation, reduced wildfire severity and woodland restoration—generally overlap with federally owned land. The remaining solutions, along with all cropland (a proxy for potential nitrogen management locations), are included within nonforest acres. Acreage totals here include land suitable for nitrogen management, resulting in a difference from the acreage totals reported in figure 4A. The numerous benefits in figure 4 and differences in ownership underscore the importance of addressing nature-based climate solutions through a variety of issues and policies.

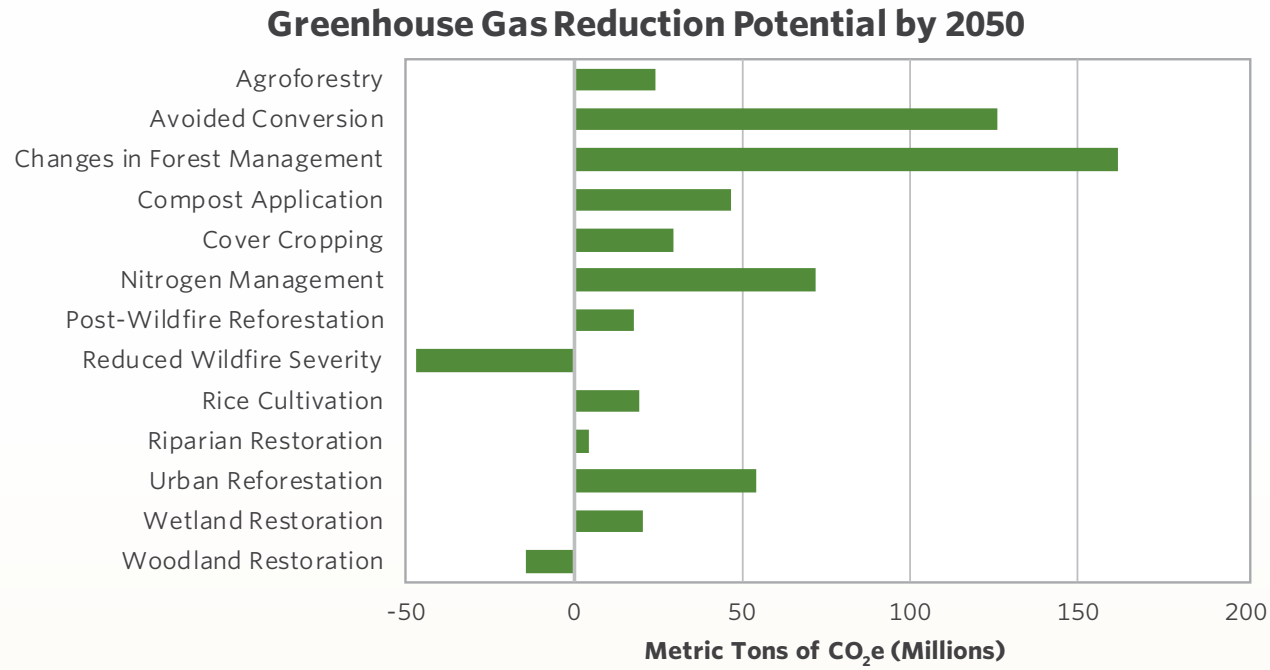


FIGURE 6. Natural and working lands hold tremendous potential for reducing greenhouse gas emissions into the atmosphere. Here, cumulative emission reduction potential—derived from three separate studies—is shown for 13 nature-based climate solutions out to the year 2050. Although negative values represent a net increase in emissions out to the year 2050, both reduced wildfire severity and woodland restoration achieve net emission reductions by the year 2021 (of 20.2 MMT CO_2e and 17.2 MMT CO_2e, respectively).

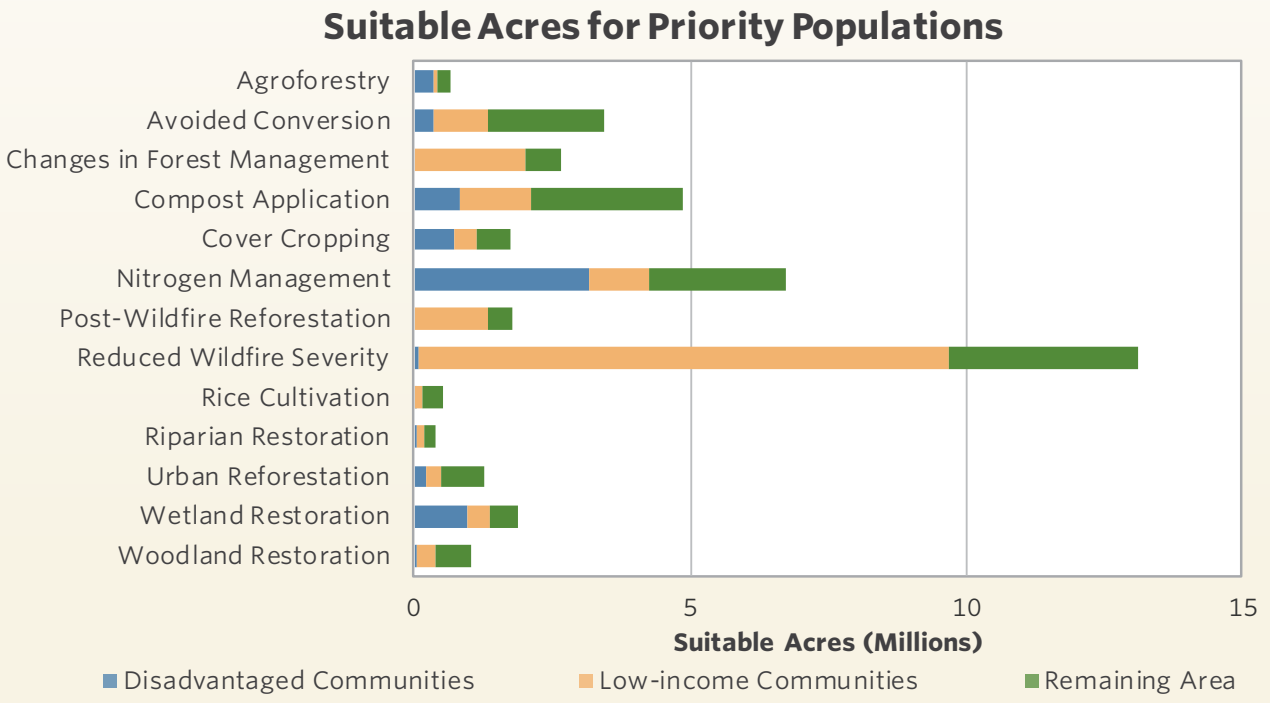
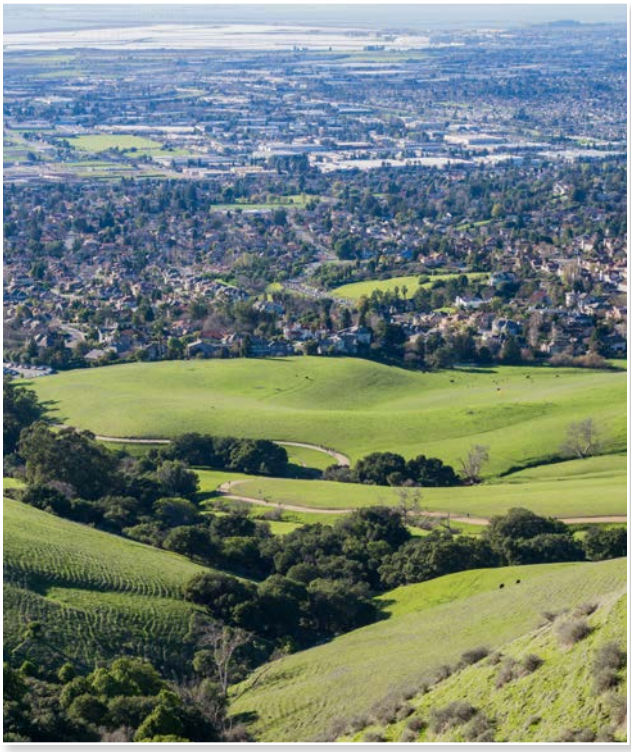


FIGURE 7. This chart illustrates the number of suitable acres for nature-based climate solutions that overlap with disadvantaged and low-income communities, as defined by the State—showing that nature-based climate solutions can produce meaningful social benefits in tandem with climate mitigation.

New policies are critical for addressing the impacts of conversion on community and individual health, as well as on GHG emissions. California's dearth of affordable housing near job centers—as well as its appetite for single-passenger car trips, reluctance to use alternative mobility options and disconnect between transportation policies and other areas of government—threaten the State's ability to protect its current and future population as well as the native species and rich natural communities that thrive in intact landscapes.

Appropriate and valuable choices for prioritizing avoided conversion could include investing in infill development, supporting local and regional policies that make redevelopment more affordable than new development, setting high fees for conversion of intact landscapes and explicitly valuing ecosystem services by including them in cost-benefit analyses for land-use decisions.

When preparing California Environmental Quality Act (CEQA) or National Environmental Protection Act (NEPA) analyses, or general plan updates, transportation agencies and local planning and permitting offices could incorporate ecosystem service valuation into cost-benefit calculations. That valuation should account for the value of the landscape being proposed for conversion, including existence value, forgone sequestration value, importance for habitat connectivity, potential for groundwater infiltration, above- and belowground carbon stores and other co-benefits. Infill parcels or other impacted parcels may prove to be far less costly to develop and may prove preferable if analyses are expanded. Scenario analysis tools like TerraCount and Comet Planner can be useful in determining the value of unconverted landscapes and their sequestration potential.



Development pressure in some areas of the state is greater than it is in others. In areas where development pressure is high, avoided conversion efforts should be prioritized. Once land is converted to a more intensive use through changes in zoning and resulting construction, the land can often lose carbon storage and mitigation value, as well as many associated co-benefits. More development follows. In a loading order of climate policies, avoided conversion (fig. 8) should be a priority, along with development projections and plans for local areas for decades to come.

AVOIDED CONVERSION

When natural and working lands are cultivated or converted into other land uses, carbon stored by the land is lost to the atmosphere. Keeping natural lands intact and healthy ensures that carbon remains in the ground and that vegetation can continue to sequester carbon from the atmosphere.

Examples of Co-benefits: Increased community cohesion, increased groundwater infiltration, improved water quality, improved air quality, more walkable and bikeable communities, and aesthetic value

Policy Levers: Sustainable Agricultural Lands Conservation Program (SGC/DOC), Agricultural Land Mitigation Program (DOC), Transformative Climate Communities Program (SGC/DOC), Williamson Act, Regional Conservation Investment Strategies (CDFW), Conservation Stewardship Program (USDA), Conservation Reserve Program (USDA), Wildlife Conservation Board (WCB) and State Conservancy easement programs, California Forest Legacy Program, California Cap-and-Trade Forest Offset Program

Cost per Metric Ton: $168 per metric ton CO_2e reduced

Social Cost of Carbon: $6.52 billion in potential savings

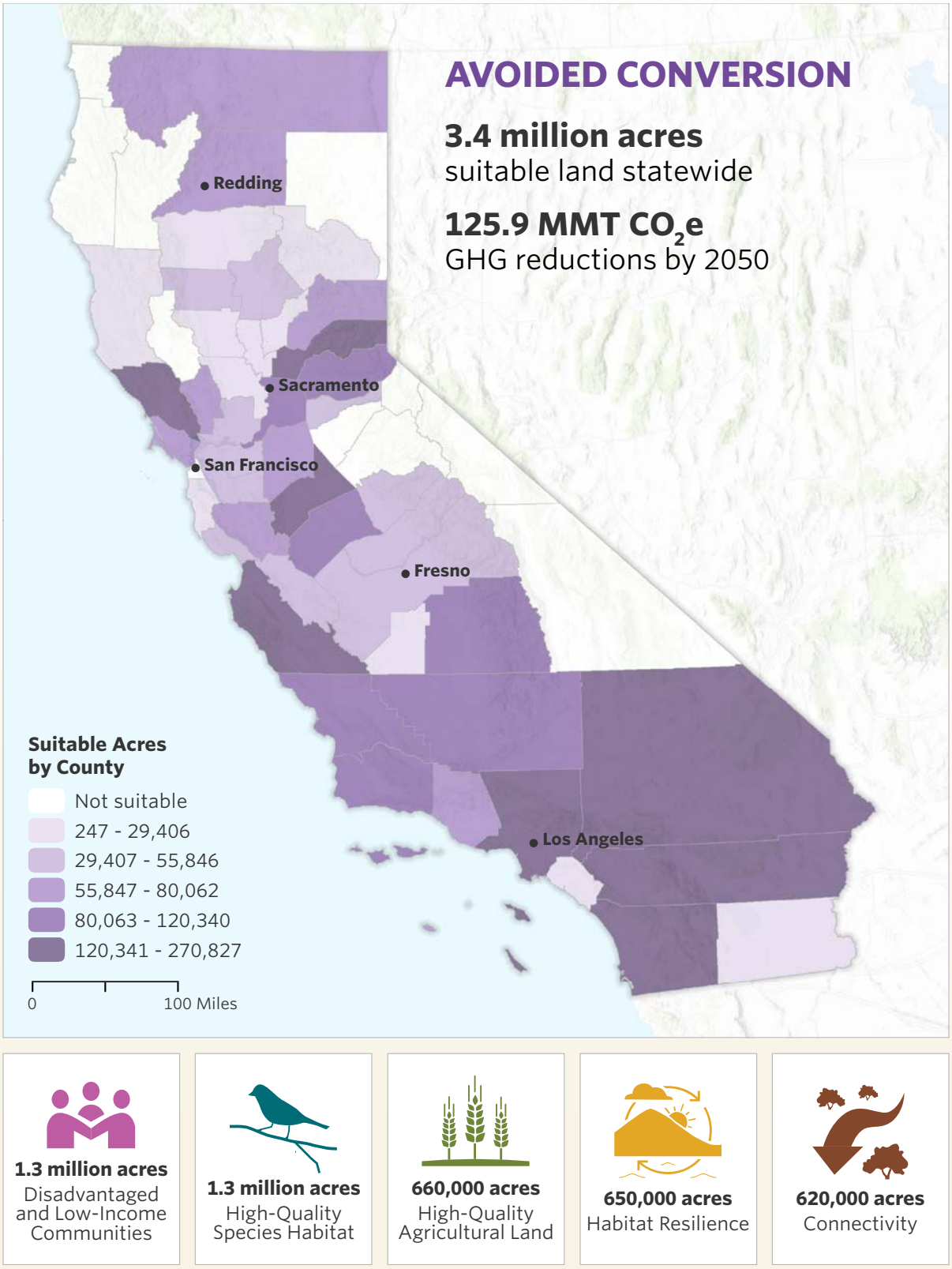


FIGURE 8. Avoided conversion. Statewide opportunity for avoided conversion, by county, with associated co-benefits for people and nature.

REFORESTING AND GREENING CALIFORNIA'S URBAN ENVIRONMENTS

California has long led the nation in investments in urban greening and street trees. Support for urban greening comes from public and private sources, including the state, local jurisdictions, electric utilities and nonprofit community groups. Examples of urban forestry programs include the Urban and Community Forestry Program at the California Department of Forestry and Fire Protection (CAL FIRE) (CAL FIRE 2020), the Free Shade Tree Program (a partnership between the Sacramento Tree Foundation and Sacramento Municipal Utility District) and the Urban and Community Forestry Program at the U.S. Department of Agriculture (USDA) Forest Service (USDA Forest Service 2020). Urban greening programs are widely accepted because their benefits tend to support many other goals, such as reducing urban heat islands, reducing energy bills, creating shaded routes to schools, cleaning air and increasing property values.

Existing California funding has been available for tree purchasing and planting, but falls short for ongoing maintenance and expansion. Additionally, funding sources—like many natural resources programs—rely on bonds, voter approval, special funds and other unprotected sources that provide no ongoing certainty to communities and organizations.

Urban greening funding should include a regular allocation from the General Fund, with additional annual funding from special funds as feasible. Currently, most funding reaches communities considered to be the most disadvantaged according to the State's CalEnviroScreen tool.[10] While this approach is good in that it prioritizes communities that likely suffer from limited urban tree cover, the approach could focus more systematically to reduce other impacts such as air pollution, heat islands and high energy bills.

By working with data from California's Department of Public Health, Energy Commission, Environmental Protection Agency (CalEPA) and Office of Environmental Health Hazard Assessment (OEHHA), as well as from CARB and other sources, CAL FIRE's Urban and Community Forestry Program could develop a statewide map to prioritize annual urban greening allocations according to factors such as percentage of tree cover, available shaded routes, urban heat island index and community-level air quality indices. The maps included in this report aggregate many of these data sources and

demonstrate how to target investments in Los Angeles (see Section III). More than a decade ago, the California State Transportation Agency (CalSTA) funded a study to identify performance measures for green streets. This study should be revisited and shared with CAL FIRE to help set metrics for streets and major arteries across the state that should receive focus as well (Macdonald et al. 2009).[11]

Additionally, State agencies could coordinate urban greening programs to reduce barriers to entry for grant applicants. This could include a common landing page for related programs and technical assistance.

Additional coordination should result in urban greening standards for any program that creates development in the state. Roads, housing, redevelopment and agricultural expansion should produce no increase in the urban heat island index, thus requiring inclusion of urban greening and other elements (such as cool roofs, green roofs, green medians and green alleys) to reduce overall development impact. CalSTA, the California Department of Housing and Community Development and the Department of Food and Agriculture (CDFA) could be advocates for urban trees and parks if, in all their programs that provide incentives for development, they require that urban trees and parks be incorporated.

Finally, a complete urban greening program could contemplate and include the life cycle of urban trees, not only funding maintenance and upkeep of urban

systems but also the reuse of urban wood waste. Taylor Guitars, a global brand with a California headquarters, turns urban tree waste into beautiful guitars (Millman 2020). The Sacramento Tree Foundation's urban wood rescue program produces usable products and feeds profits back into tree planting and maintenance (Sacramento Tree Foundation 2020). Other wood rescue programs throughout California benefit from Proposition 68 and funding from the Greenhouse Gas Reduction Fund (GGRF) for their operations, but more of these programs are necessary for a thriving system of urban trees and parks.

The spatial analysis in this report focuses on urban reforestation, which is one of many possible urban greening activities. Figure 9 shows statewide opportunities for urban reforestation, along with associated co-benefits for people and nature.

URBAN REFORESTATION

Increasing tree cover in urban areas by planting trees allows carbon to be stored above and below the ground and increases biomass that promotes additional carbon sequestration.

Examples of Co-benefits: Cooling effects during heat events, improved air quality, improved water quality and reduced water runoff, improved human health (resulting from pollution absorption, noise regulation and other factors), more walkable communities, aesthetic value

Policy Levers: Urban Greening Program (CNRA), Environmental Enhancement and Mitigation Program (CNRA), Urban and Community Forest Health Program (CAL FIRE), Transformative Climate Communities Program (SGC/DOC)

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $2.81 billion in potential savings

RESTORING CALIFORNIA'S FORESTS FOR CLIMATE AND OTHER BENEFITS

Approximately one-third of California is forested, with much of that forested land federally managed. A variety of local, State and federal rules apply to activities such as logging and restoration, depending on land management jurisdiction; the majority of California's forests are owned by the federal government, and while the State can and should play a role in accelerating forest restoration on federally owned lands, it does not have direct regulatory authority. California's 1973 Z'berg-Nejedly Forest Practice Act aims to maximize sustainable logging and extractive activities on state-managed forested landscapes while accommodating values associated with watersheds, wildlife and riparian areas, recreation opportunities and more. In addition to the Forest Practice Act, many other laws pertaining to air and water quality and species preservation, including the California and Federal Endangered Species Acts, apply to activities in all forests, regardless of jurisdictional oversight.

Forests provide countless services to Californians, including water filtration and storage, air quality, wildlife habitat, jobs and recreation opportunities. Many of California's forest systems depend on regular fire for health, succession and dispersal. Climate change, patchwork management, funding shortages and development into the wildland-urban interface (WUI) have exacerbated the incidence, severity, duration and extent of wildfires beyond a natural balance. As forests burn more severely and more often, many of the benefits they provide to the state go up in smoke. Recognizing the threat to livelihoods, community economies and forest benefits, private forest managers who focus on timber harvesting and forest conservationists who focus on maintaining or expanding protections for forests have coalesced to address these ongoing and increasing threats to the state's forests.

This coalition of government leaders, forest landowners and advocates for forest activity and health have advanced numerous plans with the goals of addressing forest health and ensuring rural economic stability. They all summarize similar ideas: Forests are in dire condition due to years of fire suppression, continued incursion into the WUI and climate change; the condition of the forests threatens the safety and health of people and ecosystems throughout the state; forest health requires stable, ongoing funding, some of which can be garnered through markets for forest goods; rural livelihoods and quality of life depend on forest health; delivering forest health will require a suite of policies spread across millions of acres, including mechanical thinning, prescribed fire, conservation easements, ongoing management and market-based actions.

These plans usually land at the State level with the recommendation that they be implemented at the local or regional level, given the heterogeneity of forest types and management statewide. There exists

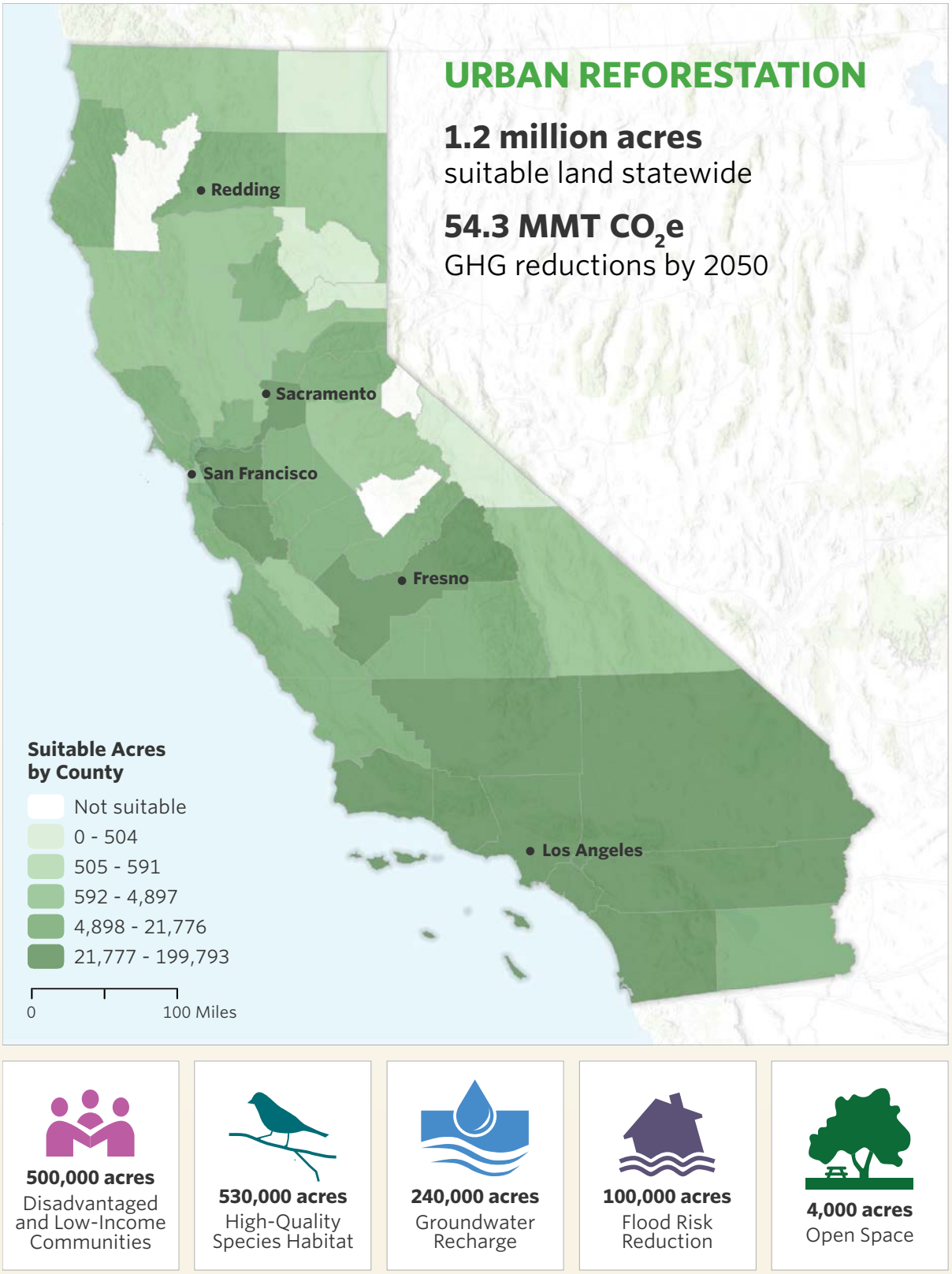


FIGURE 9. Statewide opportunity for urban reforestation, by county, with associated co-benefits for people and nature.

an opportunity to manage California's forests both as homes of commodity crops and as purveyors of valuable but noncommodity ecosystem services—if local and regional implementation can hew to statewide goals while meeting local needs. Implementation of this balanced approach requires data collection and analysis at the local level, a marriage of proposed activities with existing rules and regulations and development of local coalitions to spearhead and fund action. In areas such as the Highway 50 Corridor, the Lake Tahoe Basin and the coastal forested areas in Northern California, collaboration and information-sharing are underway.

A balanced approach to forest management could include the use of all these actions across forested acres, often with more than one action taken per acre of forest. Policies that support broader forest action include existing grant-based strategies administered by multiple departments within the CNRA, in coordination with CARB and CAL FIRE. The Legislature, stakeholders, residents of forested communities (including their county and regional leaders) and the Administration have all supported actions to reduce fire risk in forested areas and communities. To make those efforts more effective and strategic, the State could consider focusing more effort on market-based revenue sources for forest actions. These programs could include the Low Carbon Fuel Standard, ecologically responsible biomass-based energy and wood product facilities, carbon markets and other approaches that support not only forest health but also rural economic development.

There is no policy in particular that works best, or better than others. Because of the heterogeneity of forest types and forested communities, policies should be nearly surgical in their applications across the state. Priorities developed at the local and regional levels have the best chance of success; the suggestions identified in this report should be used as a starting point for local groups to identify opportunities for action. Leaders from local and state labor groups should be engaged in the conversation, ensuring that forest work is conducted in areas where jobs are being lost because industries are waning. Figures 10, 11, 12, 13 and 14 show statewide opportunities related, respectively, to reduced wildfire severity, post-wildfire reforestation, changes in forest management, riparian restoration and woodland restoration.

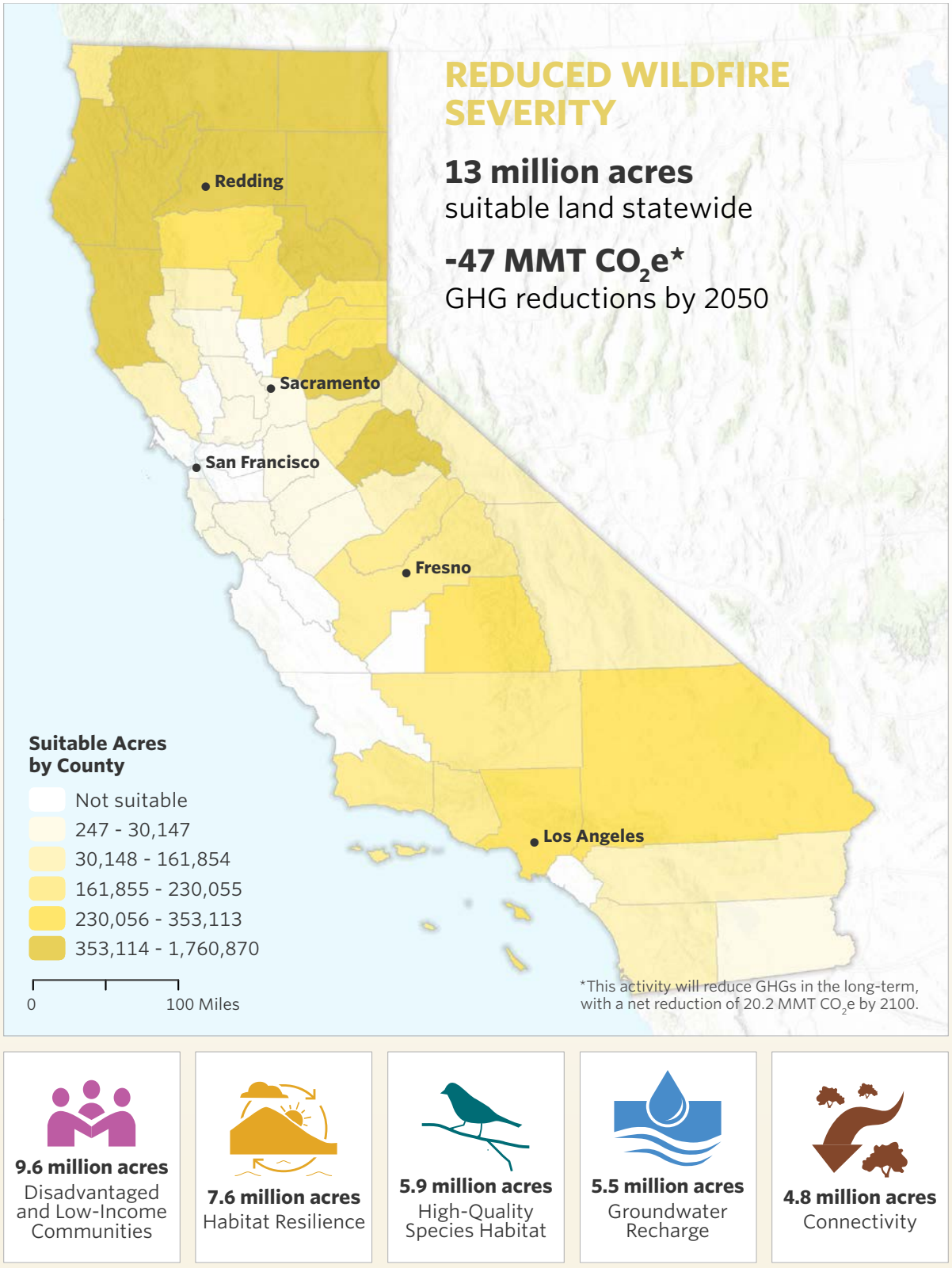


FIGURE 10. Statewide opportunity for reduced wildfire severity, by county, with associated co-benefits for people and nature. This is just one solution among many that can help reduce fire risk and associated emissions.

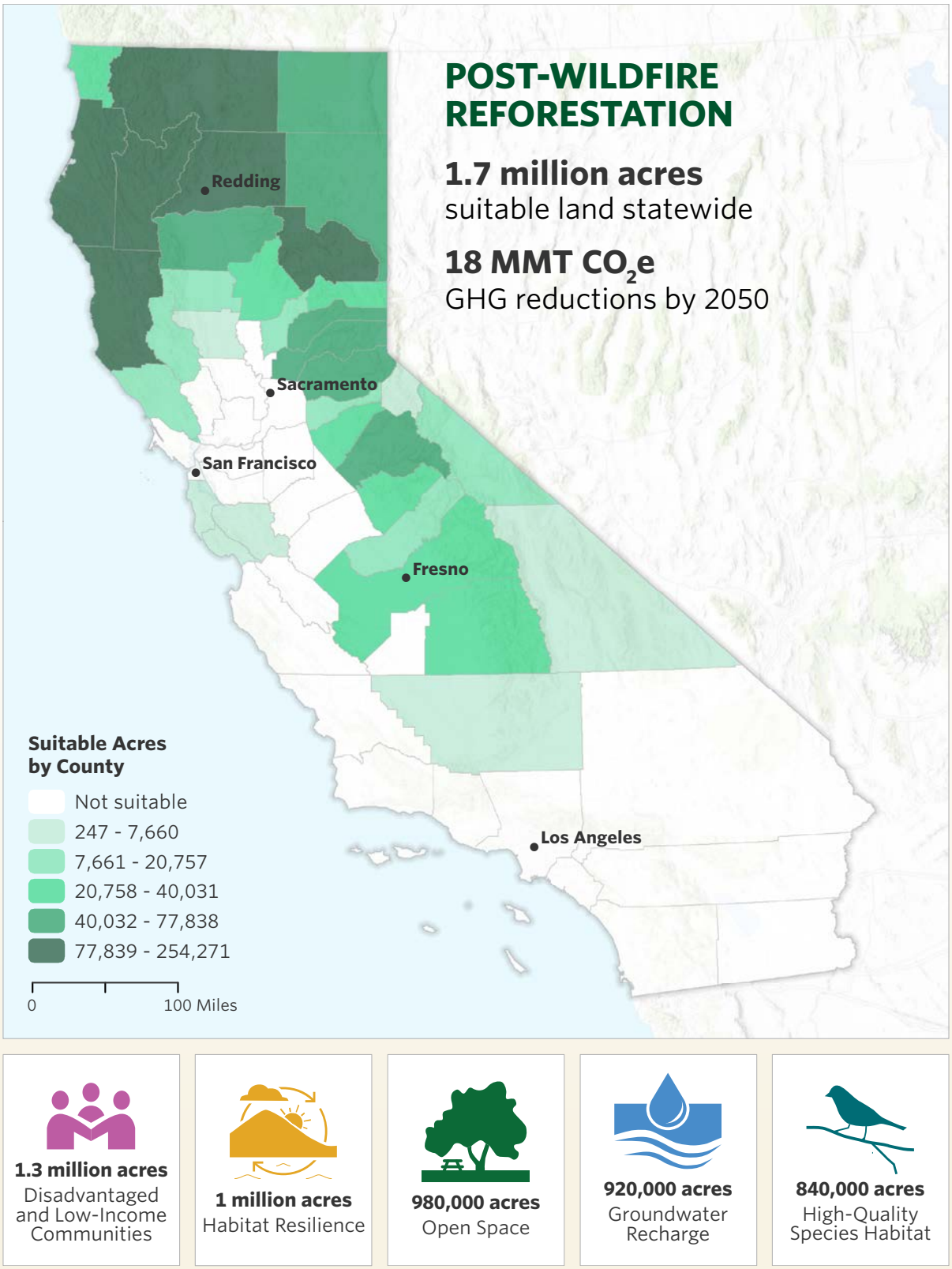


FIGURE 11. Statewide opportunity for post-wildfire reforestation, by county, with associated co-benefits for people and nature.

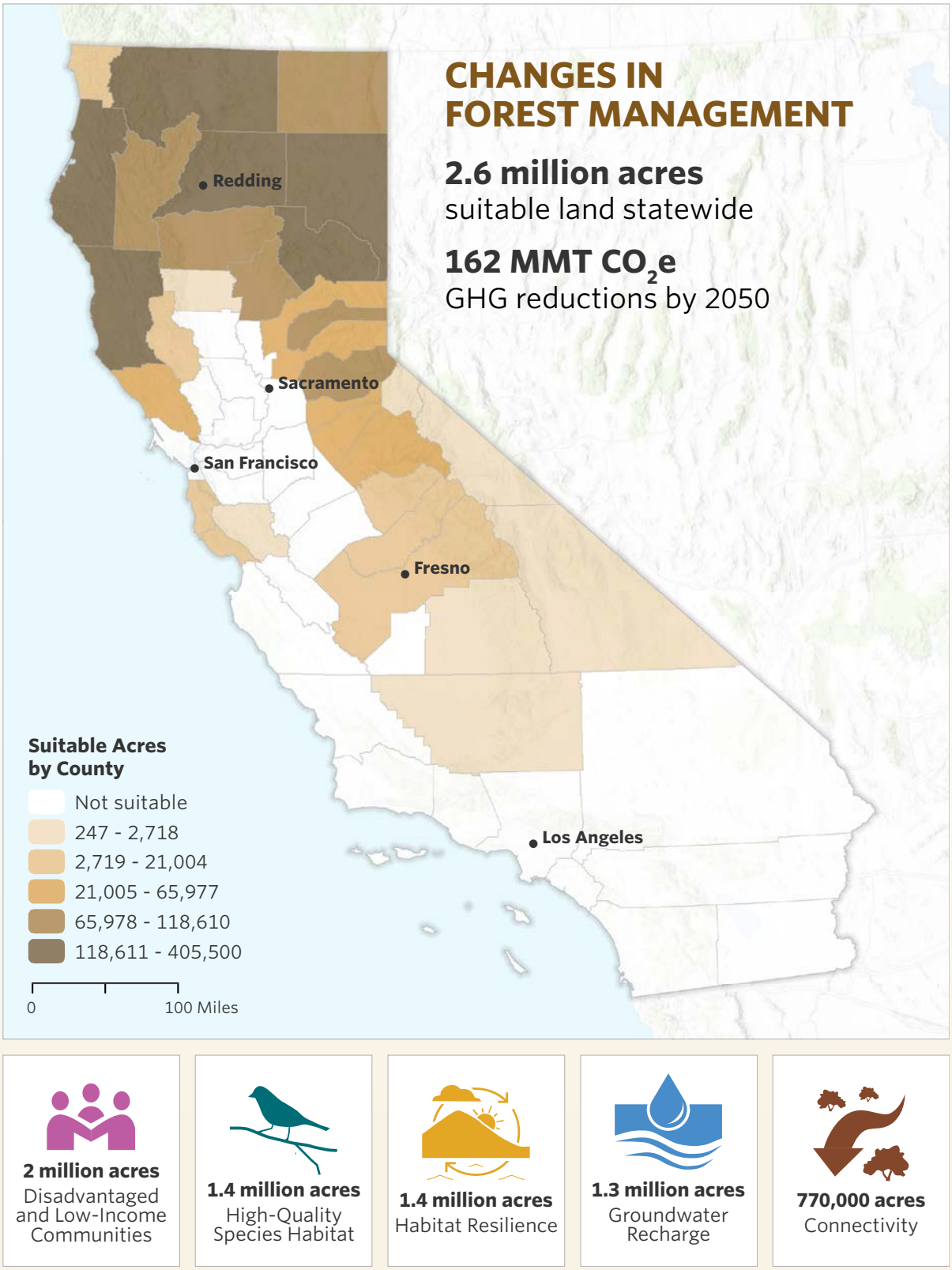


FIGURE 12. Statewide opportunity for changes in forest management, by county, with associated co-benefits for people and nature.

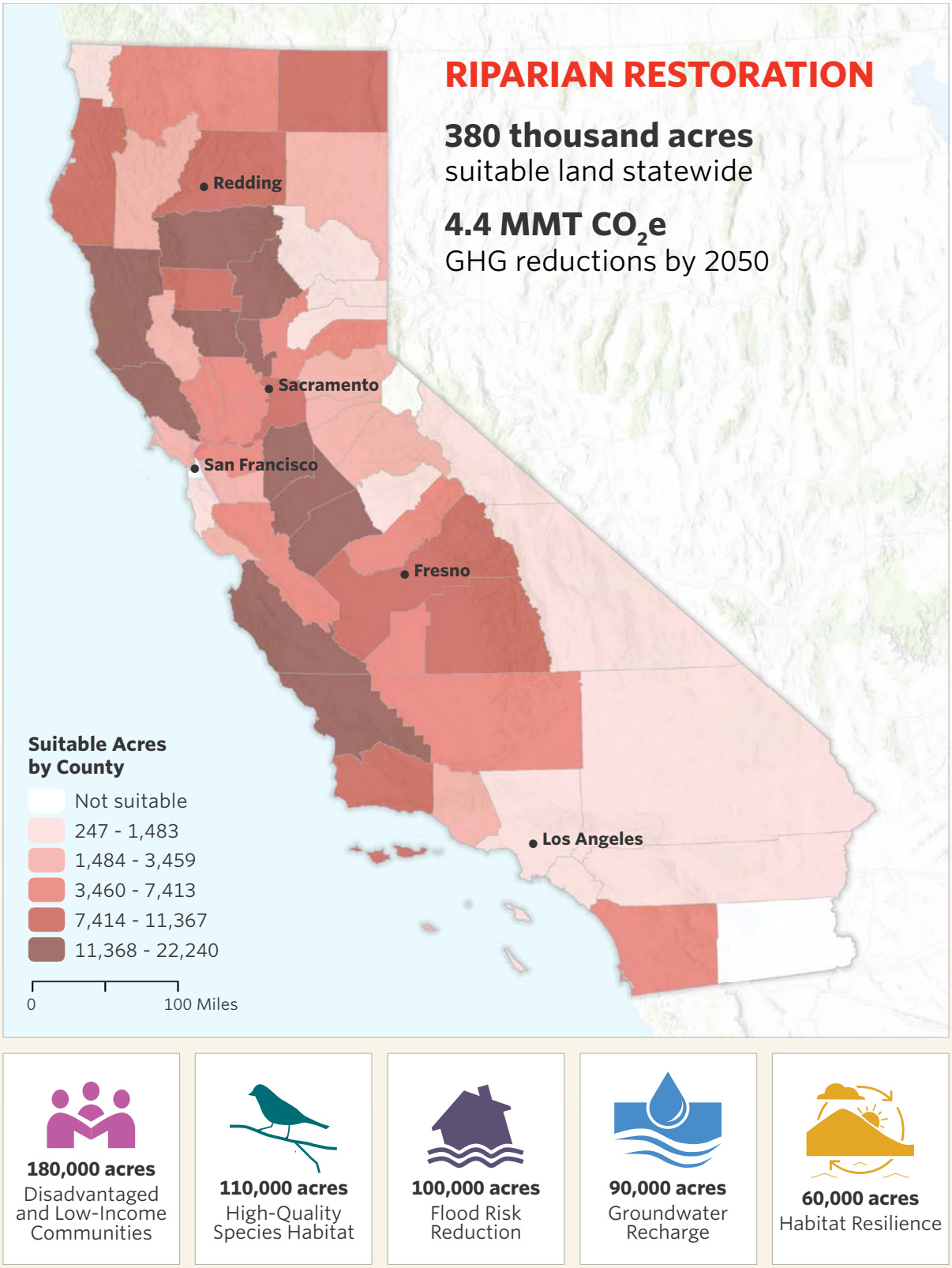


FIGURE 13. Statewide opportunity for riparian restoration, by county, with associated co-benefits for people and nature.

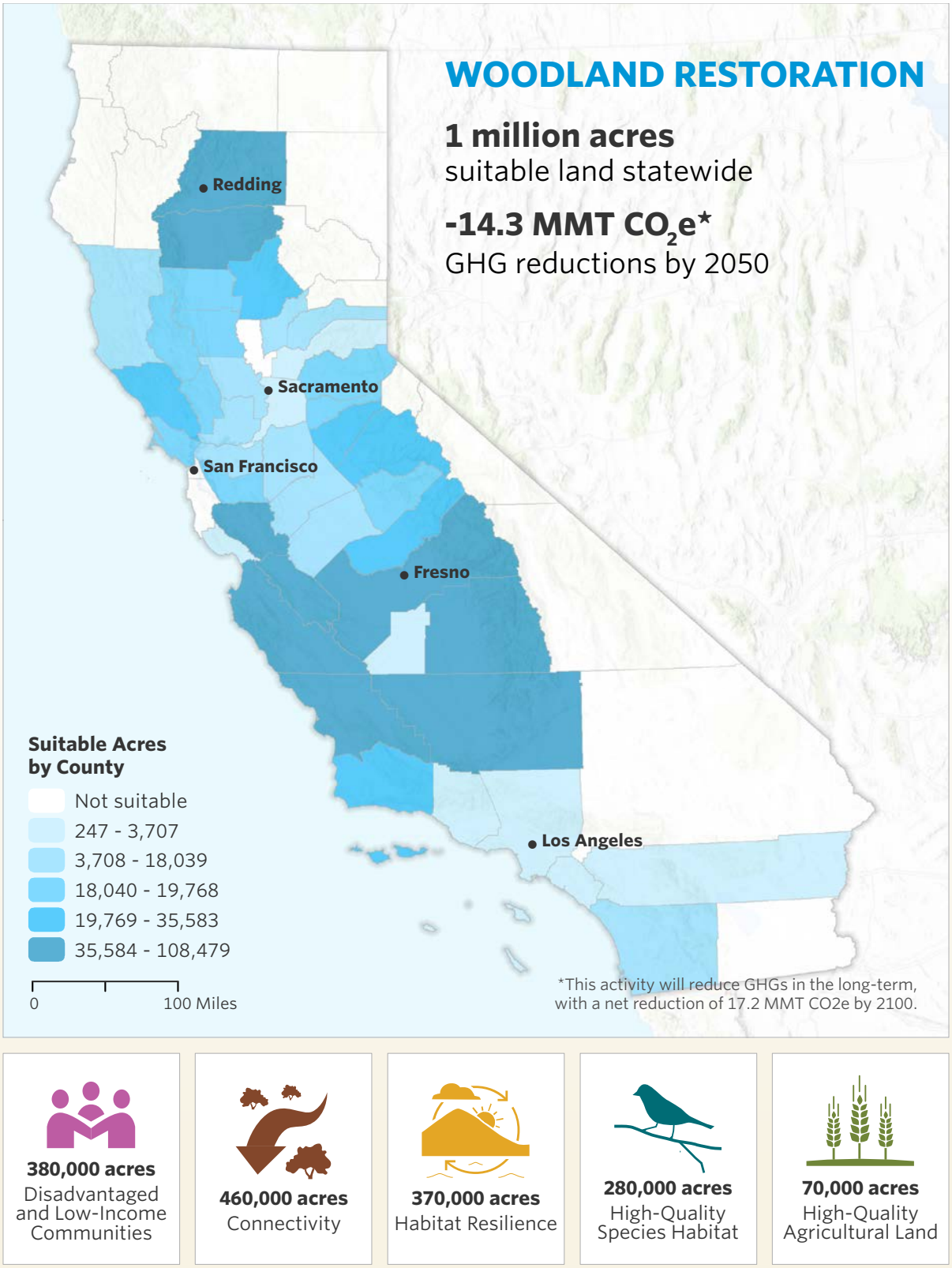


FIGURE 14. Statewide opportunity for woodland restoration, by county, with associated co-benefits for people and nature.

REDUCED WILDFIRE SEVERITY

A number of forest management practices—including treatments like thinning and prescribed burns—can be used to reduce fuel loading and forest overcrowding, in turn reducing the severity of wildfire events. Because these practices remove carbon from the forest, they result in net emissions for a number of years. Over time, as these treatments prevent high-severity wildfires and remaining trees grow larger, the carbon loss is "paid back" through avoidance of emissions from high-severity fire. The rate of payback is dependent on a number of factors.

Examples of Co-benefits: Improved habitat for wildlife, reduced flood risks, improved security for water supplies, improved recreational space, products for energy or consumer goods (timber, biomass)

Policy Levers: Habitat Enhancement and Restoration Program (WCB), Timberland Conservation Program (CDFW), Forest Health Grant Program (CAL FIRE), California Forest Health and Fire Prevention Program (CAL FIRE), California Forest Improvement Program (CAL FIRE), California Vegetation Treatment Program (CAL FIRE), Sierra Nevada Watershed Improvement Program (SNC)

Cost per Metric Ton: Not applicable[12]

Social Cost of Carbon: Not applicable

POST-WILDFIRE REFORESTATION

Actively replanting trees in areas that burned during moderate or severe wildfires accelerates the regeneration of forests and produces storage for carbon.

Examples of Co-benefits: Improved habitat for wildlife, improved water quality, reduced flood risks, improved recreational space, aesthetic value

Policy Levers: Forest Health Grant Program and California Forest Improvement Program (CAL FIRE), Timberland Conservation Program (CDFW), Forest Conservation Program (WCB), Emergency Forest Restoration Program (USDA)

Cost per Metric Ton: $16 per metric ton CO_2e reduced

Social Cost of Carbon: $932 million in potential savings

CHANGES IN FOREST MANAGEMENT

Carbon stocks in forests can be increased with changes in forest management. These changes include strategies such as increasing harvest rotation age and shifting harvest practices away from clear-cutting.

Examples of Co-benefits: Improved habitat for wildlife, improved water quality

Policy Levers: California Forest Improvement Program (CAL FIRE), Timberland Conservation Program (CDFW), Climate Adaptation and Resiliency Program (WCB), California Forest Legacy (CAL FIRE), California Cap-and-Trade Forest Offset Program

Cost per Metric Ton: $28 per metric ton CO_2e reduced

Social Cost of Carbon: $8.39 billion in potential savings

RIPARIAN RESTORATION

Establishing forest cover along the banks of streams and rivers in agricultural and grassland regions leads to added carbon sequestration.

Examples of Co-benefits: Improved habitat for wildlife, reduced flood risks, improved water quality, improved recreational space, aesthetic value

Policy Levers: Urban Streams Restoration Program (DWR), Flood Corridor Program (DWR), Stream Flow Enhancement Program (WCB), Riparian Habitat Conservation Program (WCB), Healthy Soils Program (CDFA), Working Lands and Riparian Corridor Program (DOC)

Cost per Metric Ton: $558 per metric ton CO_2e reduced

Social Cost of Carbon: $228 million in potential savings

WOODLAND RESTORATION

Restoring native oak species by replanting provides carbon storage, along with numerous additional environmental and social benefits.

Examples of Co-benefits: Improved habitat for wildlife, improved recreational space, controlled soil erosion, improved groundwater recharge, improved water quality, improved air quality, temperature moderation, aesthetic value

Policy Levers: Oak Woodland Conservation Program (WCB), Climate Adaptation and Resiliency Program (WCB), Environmental Quality Incentives Program (USDA)

Cost per Metric Ton: Not applicable[13]

Social Cost of Carbon: Not applicable


Photo: Kevin Arnold


Photo: Erika Nortemann/TNC

FARMING AND CONSERVATION PRACTICES FOR HEALTHY SOILS AND CARBON SEQUESTRATION

California is home to 69,400 farms and ranches, situated on 24.3 million acres of land (CDFA 2019). These farms generated $50 billion in revenue in 2018, with dairy, grapes and almonds accounting for $18.2 billion, or 36%, of total cash receipts. California's farms lead the nation in terms of cash receipts, representing 13% of the entire U.S. agricultural economy. The state is also home to 40% of all the organic production in the country, totaling more than $10 billion in organic product sales in 2018 (USDA 2019). The majority of California's agricultural sales occurred in Kern, Monterey, Fresno and Sonoma Counties and the vast majority of processing occurred in Los Angeles County. Agriculture employs more than 800,000 people statewide (Martin 2016).

Agricultural policy has a long history in California, often interconnected with water policy. The inclusion of climate change and climate modeling in agricultural policy is more recent, having begun over the past decade. California farmers have long adapted to interannual weather and water variability by rotating pasture, favoring multiple crops over monocultures and generally implementing systems and practices that accord with their years of experience and shared histories. As the climate changes more rapidly, more adaptation and incentives will be necessary to maintain California's role in providing food and fiber to the nation and the world.

Existing policies support farmers by helping them to purchase lower-emission heavy-duty farm equipment, install drip and low-flow irrigation, access lower-emission shuttles from housing centers to jobs and implement practices to enhance and increase soil carbon sequestration. Additionally, the State has funded the development of affordable and efficient housing for farmworkers. Another path toward reducing emissions associated with agriculture would involve further downscaling of climate models to ecoregions throughout the state. Such initiatives help farmers understand issues such as where and how the landscape will change most rapidly and where extreme events and rapid warming will cause the greatest impact.

This type of technical assistance has been provided for decades by regional conservation districts (RCDs), county agricultural commissioners, the U.S. Department of Agriculture and University of California Cooperative Extension. Coordination occurs from the federal level to the local level, often more effectively than in other sectors. Existing policies for farmers, like those described above, are implemented through different incentive programs that span multiple agencies. Yet, many of these programs are closely related. A stronger approach could involve increasing the coordination of incentive programs and tailoring them to better match growing seasons. Reporting for grant programs could also better match the types of data that farmers already collect.

Finally, programs could allow and account for the implementation of multiple solutions on the same acre. The CDFA Office of Environmental Farming and Innovation works to aggregate many climate-smart agriculture programs. It could strive to align programs so that counties, RCDs and farms can work together on strategies to preserve prime agricultural land—while overlaying that land with policies included in this report, such as agroforestry and cover cropping. Furthermore, the accounting of GHG emissions and reductions from strategic land management should include landscape carbon, not just avoided emissions from VMT or diesel equipment.

The policies described and mapped in this report, if implemented, could dramatically enrich active and fallowed farmlands and rangelands, help contribute to the goals of California's Sustainable Groundwater Management Act (SGMA), reduce subsidence and increase productivity, jobs and technical expertise. Further, California agriculture could be one of the first jurisdictions to implement climate-smart management across all farms, regardless of size.

Figures 15, 16, 17, 18 and 19 show statewide opportunities related, respectively, to agroforestry, cover cropping, compost application, nitrogen management and rice cultivation.

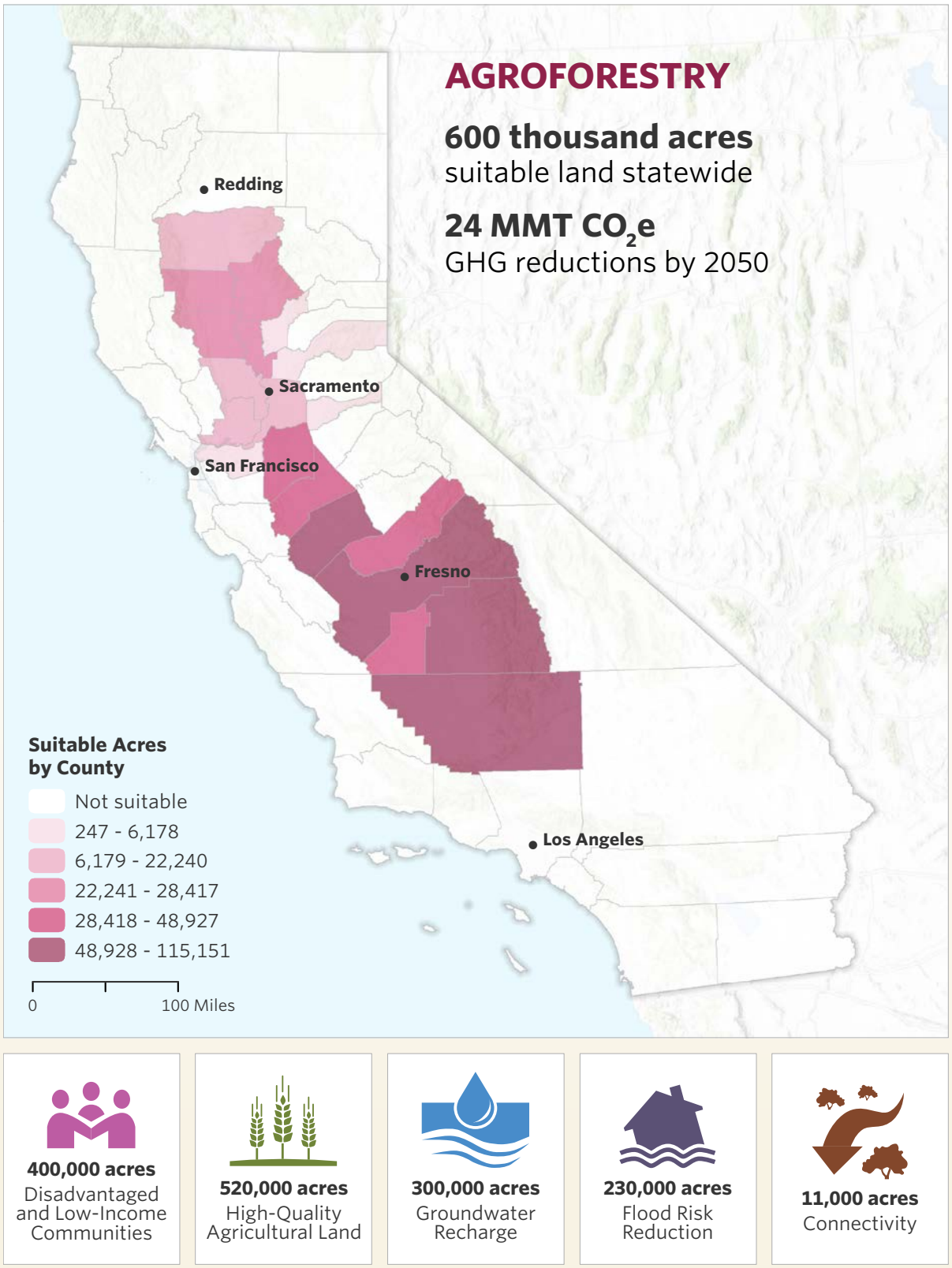


FIGURE 15. Statewide opportunity for agroforestry, by county, with associated co-benefits for people and nature.

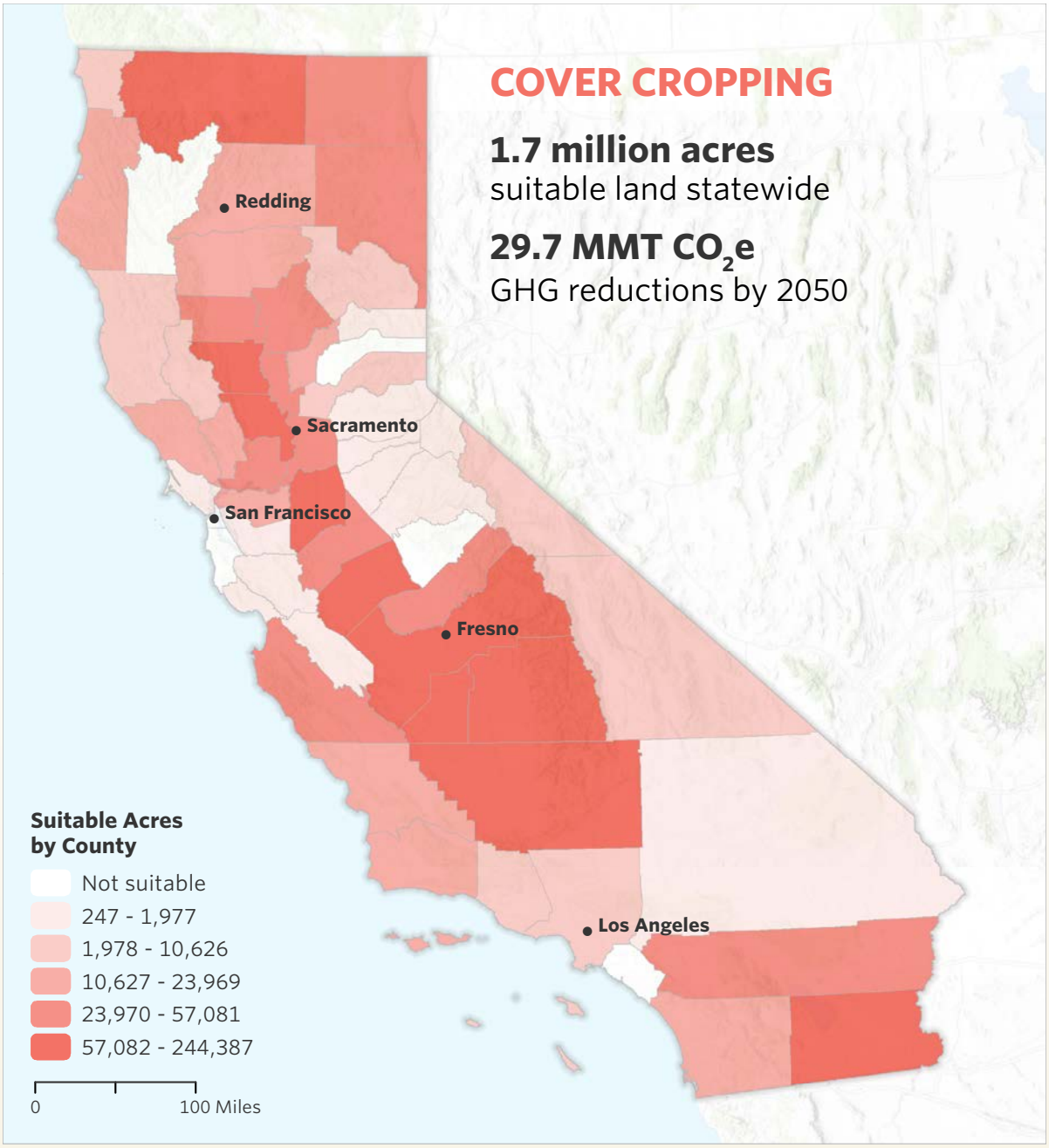


FIGURE 16. Statewide opportunity for cover cropping, by county, with associated co-benefits for people and nature.

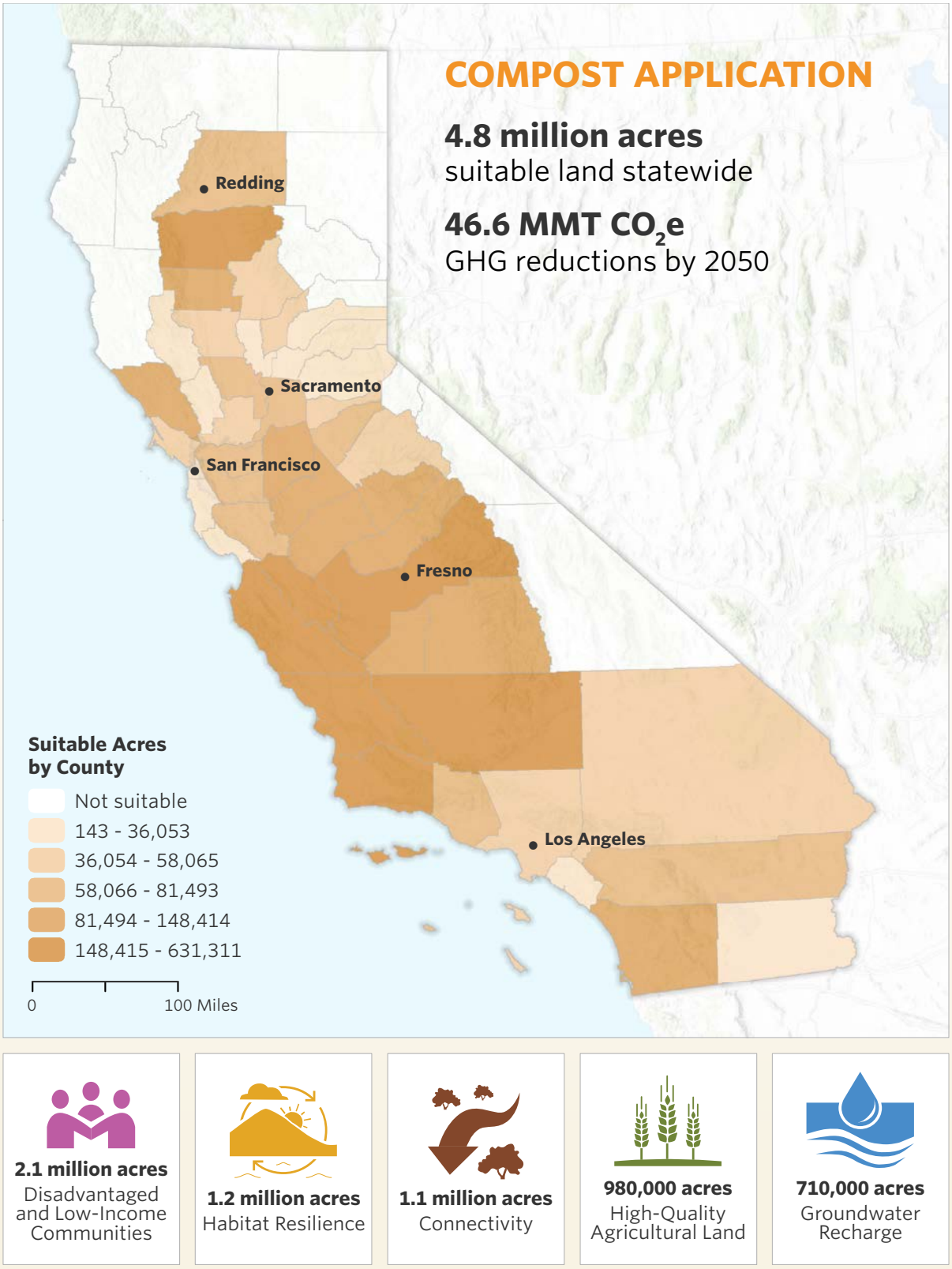


FIGURE 17. Statewide opportunity for compost application, by county, with associated co-benefits for people and nature.

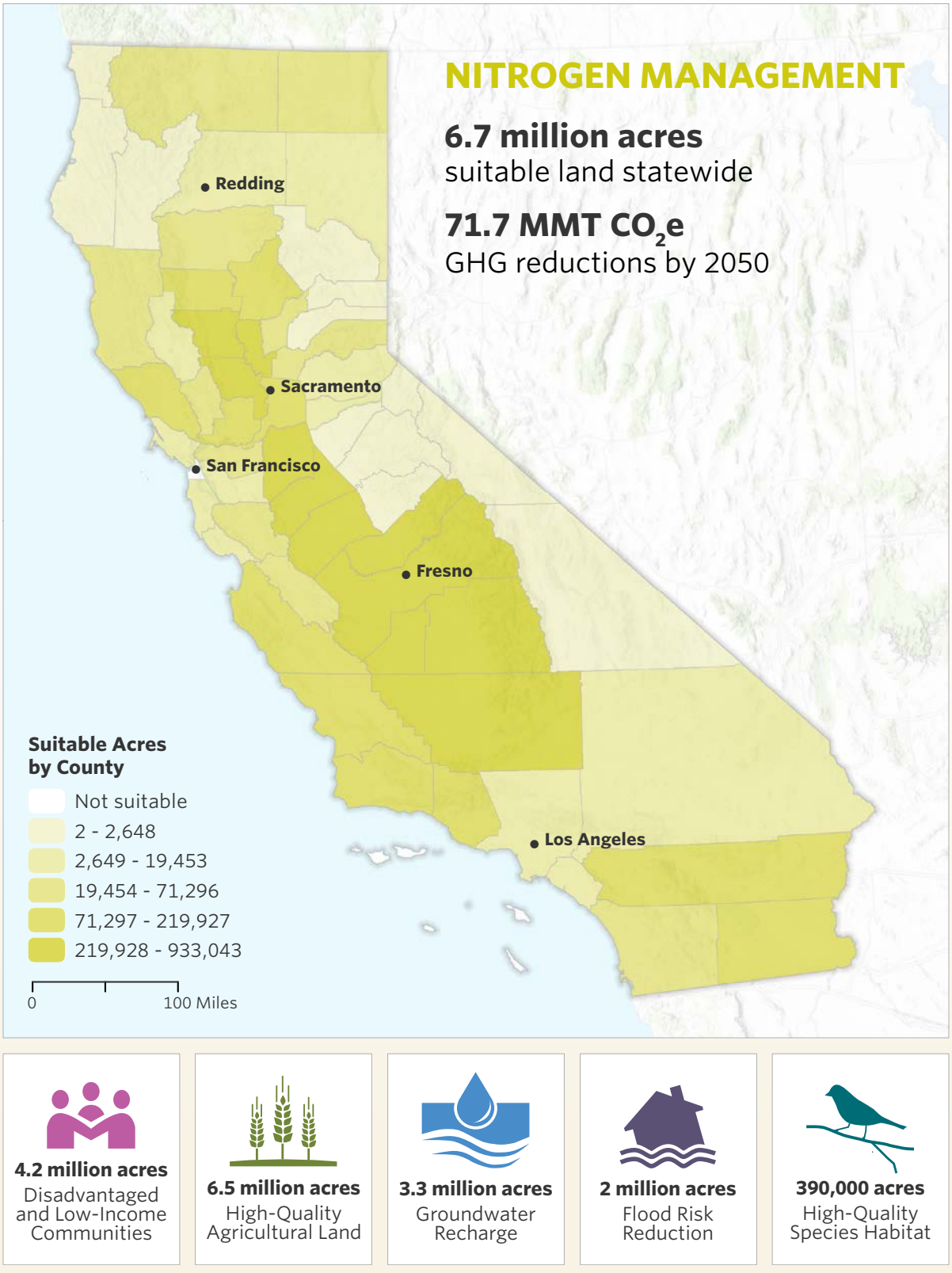


FIGURE 18. Statewide opportunity for nitrogen management on cropland, by county, with associated co-benefits for people and nature. Here, suitable acres have been determined using available cropland data (see Appendix B for details).

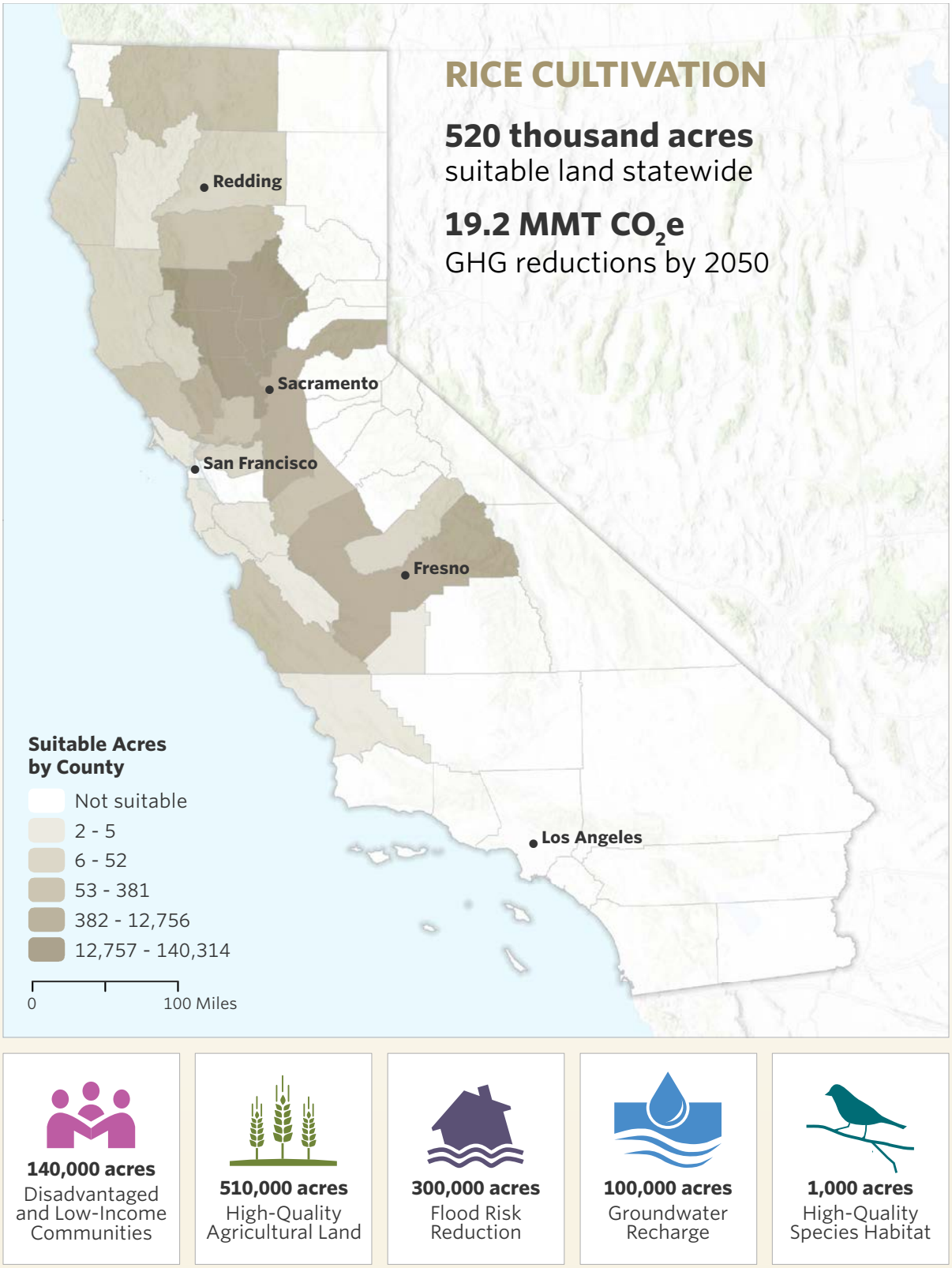


FIGURE 19. Statewide opportunity for rice cultivation, by county, with associated co-benefits for people and nature.

AGROFORESTRY

Establishing trees or hedgerows around the boundaries of crops or pastureland significantly increases carbon stocks while providing shade and windbreak benefits.

Examples of Co-benefits: Improved crop yields, controlled soil erosion, reduced runoff, improved soil nutrients, improved habitat stability, climate connectivity, improved groundwater recharge

Policy Levers: Ecosystem Restoration on Agricultural Lands (WCB), Healthy Soils Program (CDFA), Technical Assistance Grant Program (CDFA), Conservation Reserve Program (USDA), Environmental Quality Improvement Program (USDA)

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $1.24 billion in potential savings

COVER CROPPING

Rotating nonmarketable crops in the fallow season between main crops improves soil health and carbon sequestration.

Examples of Co-benefits: Improved groundwater recharge, improved land productivity, improved water quality

Policy Levers: Healthy Soils Program (CDFA), Technical Assistance Grant Program (CDFA), Conservation Reserve Program (USDA), Regional Conservation Partnership Program (USDA), Environmental Quality Incentives Program (USDA)

Cost per Metric Ton: $39 per metric ton CO_2e reduced

Social Cost of Carbon: $1.54 billion in potential savings

COMPOST APPLICATION

Adding compost to grasslands increases soil carbon sequestration.[14]

Examples of Co-benefits: Increased crop yield, reduced food waste (from compost production), erosion control

Policy Levers: Healthy Soils Program (CDFA), Technical Assistance Grant Program (CDFA)

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $295 million in potential savings

NITROGEN MANAGEMENT

Using nitrogen fertilizers more efficiently reduces in-field and upstream emissions.

Examples of Co-benefits: Improved land productivity, improved water quality, increased groundwater recharge

Policy Levers: Fertilizer Research and Education Program (CDFA), Environmental Quality Incentives Program (USDA), Conservation Stewardship Program (USDA)

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $3.71 billion in potential savings

RICE CULTIVATION

Improved practices in rice cultivation—including midseason drainage, alternate wetting and drying, and residue removal—reduce methane and nitrous oxide emissions.

Examples of Co-benefits: Improved habitat for wildlife, increased groundwater recharge, improved land productivity, improved water quality

Policy Levers: Regional Conservation Partnership Program (USDA), Rice Management Offset Protocol under California's cap-and-trade program

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $994 million saved

RESTORING AND MAINTAINING WETLANDS FOR CLIMATE PROTECTION

Mining, diking, farming and urbanization have reduced the extent of natural wetlands, including vernal pools, coastal wetlands and riparian areas, by 75% to 97% across the state (CWQMC 2013). The importance of wetlands as areas for thriving biodiversity, protection from stormwater surges, fishing and other forms of recreation, groundwater filtration and carbon sequestration is widely known and celebrated—yet policies have not kept pace with the need to preserve and expand wetlands.

Section 404 of the Federal Clean Water Act (CWA), passed in 1972, regulates filling and dredging wetlands. Wetlands across California were filled and dredged before the inception of the CWA, but continue to be impacted by new housing development, farming and transportation infrastructure. The definition of "navigable waters" has been a contested point for administering the CWA. After several rulings by federal courts, the definition of "waters of the United States" was updated in 2015 to greatly expand the definition of navigable waters and potentially offer much greater protection for wetlands. In 2019, the U.S. Environmental Protection Agency (EPA) reversed course and rejected the 2015 rule, threatening the security of remaining wetlands (DOD/EPA 2019). The same year, the State Water Resources Control Board adopted a State designation for wetlands, serving as a backstop for protection when the EPA later released the

Navigable Waters Protection Rule, stating that wetlands are only those "adjacent to other jurisdictional waters" (DOD/EPA 2020; California Water Boards 2019).

Multiple conservancies and organizations, from those that focus on specific individual wetlands to those that focus on entire systems like the Sacramento-San Joaquin Delta, exist across California. Engaging local residents on the importance of wetlands in their immediate communities through local advocacy is imperative. State and national advocacy is also critical in helping local groups coalesce around legal definitions and actions for wetland preservation and expansion.

As California aims to expand housing availability and, with it, transportation infrastructure, leaders from the Legislature, Administration and agencies overseeing housing and transportation expansion should engage with natural resource, water and land-use experts to understand the benefits and risks of impacts on wetlands. The maps and resources contained in this report show areas where wetland restoration can confer benefits on all Californians. These maps could be used to educate local elected officials about the areas where wetlands work can occur, the ways in which restoration of those areas could help constituents and the resources and services that would be lost if those wetlands disappeared.[15]

New policies implemented should account for the myriad climate and other benefits conferred by wetlands—and could support the goal of allowing no further loss of existing wetlands while also achieving an annual percentage gain in wetland areas in the state.

Figure 20 maps statewide opportunities related to wetland restoration.

WETLAND RESTORATION

Restoring wetlands can prevent emissions from drained soils while increasing carbon stocks.[16]

Examples of Co-benefits: Improved habitat for wildlife, reduced flood risks, stream bank and shoreline preservation, improved stormwater management, improved water quality, added recreational opportunities

Policy Levers: Environmental Enhancement and Mitigation Program (CNRA), Inland Wetlands Conservation Program (WCB), Climate Adaptation and Resiliency Program (WCB), Ecosystem Restoration on Agricultural Lands (WCB), Hazard Mitigation Program (FEMA), Regional Conservation Partnership Program (USDA), One Bay Area Grant Program (MTC), Wetlands Restoration for GHG Reductions Program (CDFW)

Cost per Metric Ton: Not applicable

Social Cost of Carbon: $1.05 billion in potential savings

Photo: Kiiiii Yuyan

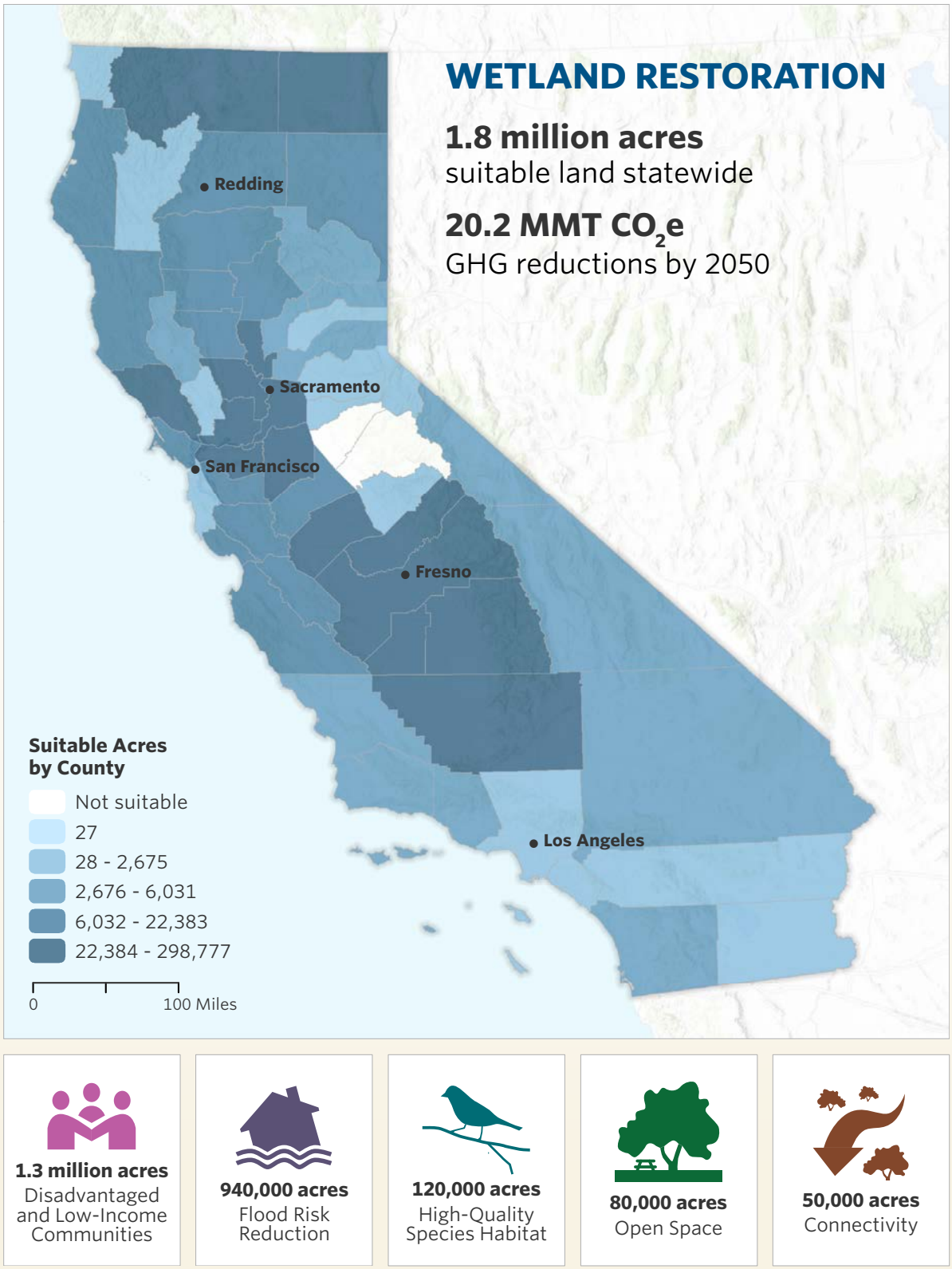


FIGURE 20. Statewide opportunity for wetland restoration, by county, with associated co-benefits for people and nature. This solution includes coastal and inland wetlands (see Appendix B for details).

FIGURE 21. Regions of California. This report divides the state into six regions, as shown, to provide regional policy context for implementing nature-based climate solutions in California. Case studies, identified as points on this map, are used to identify policy levers and recommendations to scale up climate action with nature-based solutions.

III. Leveraging Nature-based Climate Solutions: Regional and Local Perspectives

Each of the actions and policies discussed and mapped in Section II can stand alone in an implementation plan or bill, targeting acreage or GHG benefits facilitated by each action. A more effective plan to operationalize these actions is to focus a suite of policies that meets community, landscape and regional needs while delivering significant GHG emission reductions and associated community and ecosystem benefits.

The following case studies highlight policy ideas and recommendations that can address regional needs and climate goals while also supporting statewide efforts to become carbon-neutral. These case studies focus on five regions (fig. 21) with similar ecological and population characteristics—such as those with a greater proportion of forested landscapes and dispersed rural communities, or arid landscapes with a greater proportion of urbanized areas. The case studies include references to federal, State and local policies that can deliver meaningful and measurable reductions in GHG emissions and increased benefits in other, related categories. Where there are gaps in policies, the case studies identify policy opportunities for State leaders to allocate resources to meet demand.

Figure 22 illustrates the breadth of opportunity for nature-based solutions within each region. The case studies that follow in this section showcase select solutions and policy recommendations to support their implementation in the region and statewide.

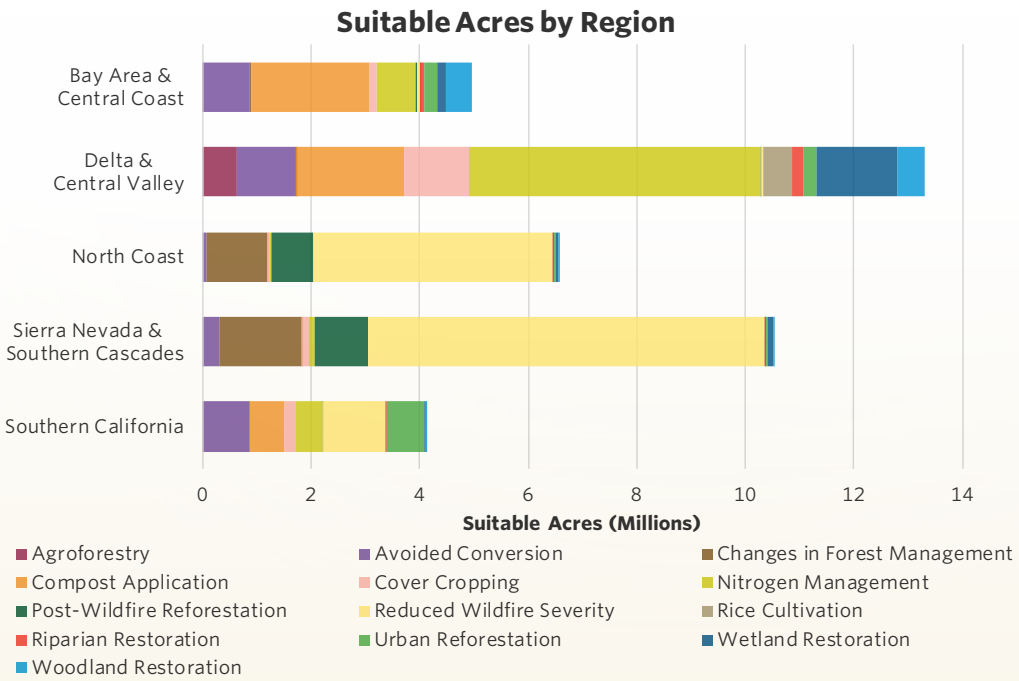


FIGURE 2. Suitable acres, by region, for nature-based solutions. Opportunity for nature-based climate solutions across different regions in California. Opportunity is reported in terms of acres suitable for each solution within each region.

NORTH COAST

North Coast

NBS Reduction Opportunities: changes in forest management, reduced wildfire severity, rice cultivation, riparian restoration, avoided conversion, urban reforestation, wetland restoration

Climate Impact Protection:[17] Fire risk reduction, flood attenuation, protection against sea level rise, habitat connectivity, urban heat island reduction, air quality

County Climate Action:[18] Humboldt, Sonoma, Lake, Tehama, Shasta, Colusa

California Climate Investments:[19] $80.83 million

Case Study Focus: Carbon markets, conservation easements, California Climate Investments

The North Coast is a region rich in natural resources. It has extensive forestland, much of which is managed timberland owned by both large and small landowners. It also serves as critical habitat for threatened and endangered species like coho and chinook salmon, northern spotted owls and marbled murrelets. Based on our analysis, a variety of nature-based greenhouse gas reduction solutions could be applied in this region, including changes in forest management, rice cultivation, riparian restoration, avoided conversion, urban reforestation and wetland restoration. Implementation of these solutions could not only help reduce emissions and sequester carbon but also help preserve habitat for fish and wildlife—as well as safeguard communities from climate impacts like sea level rise, flooding and enhanced fire risk. Figure 23 shows statewide opportunities and co-benefits available in the North Coast.

The Buckeye Forest example described below focuses on the innovative application of two policies and programs—conservation easements and California's forest carbon market—that could support greenhouse gas reductions and lead to additional benefits from changes in forest management. While a variety of solutions and policies can, and should, support GHG reduction in the region, these programs and solutions show promise for being scaled up in the region and elsewhere across the state. Using the Buckeye Forest example, we provide recommendations below for how the State might accelerate action across California.

Buckeye Forest, Sonoma County: Leveraging climate benefits through improved forest management and conservation with public and private funding

The Buckeye Forest (figs. 24 and 25), owned by The Conservation Fund, is located in northern Sonoma County and covers 30 square miles of the Gualala River watershed. It includes roughly 20,000 acres of natural communities that include redwoods, Douglas fir, oak woodland, chaparral and grasslands. Before The Conservation Fund purchased the land, plans called for this property to be subdivided into 60 parcels—and for 1,800 acres of vineyards to be developed in scattered locations across the property—resulting in the

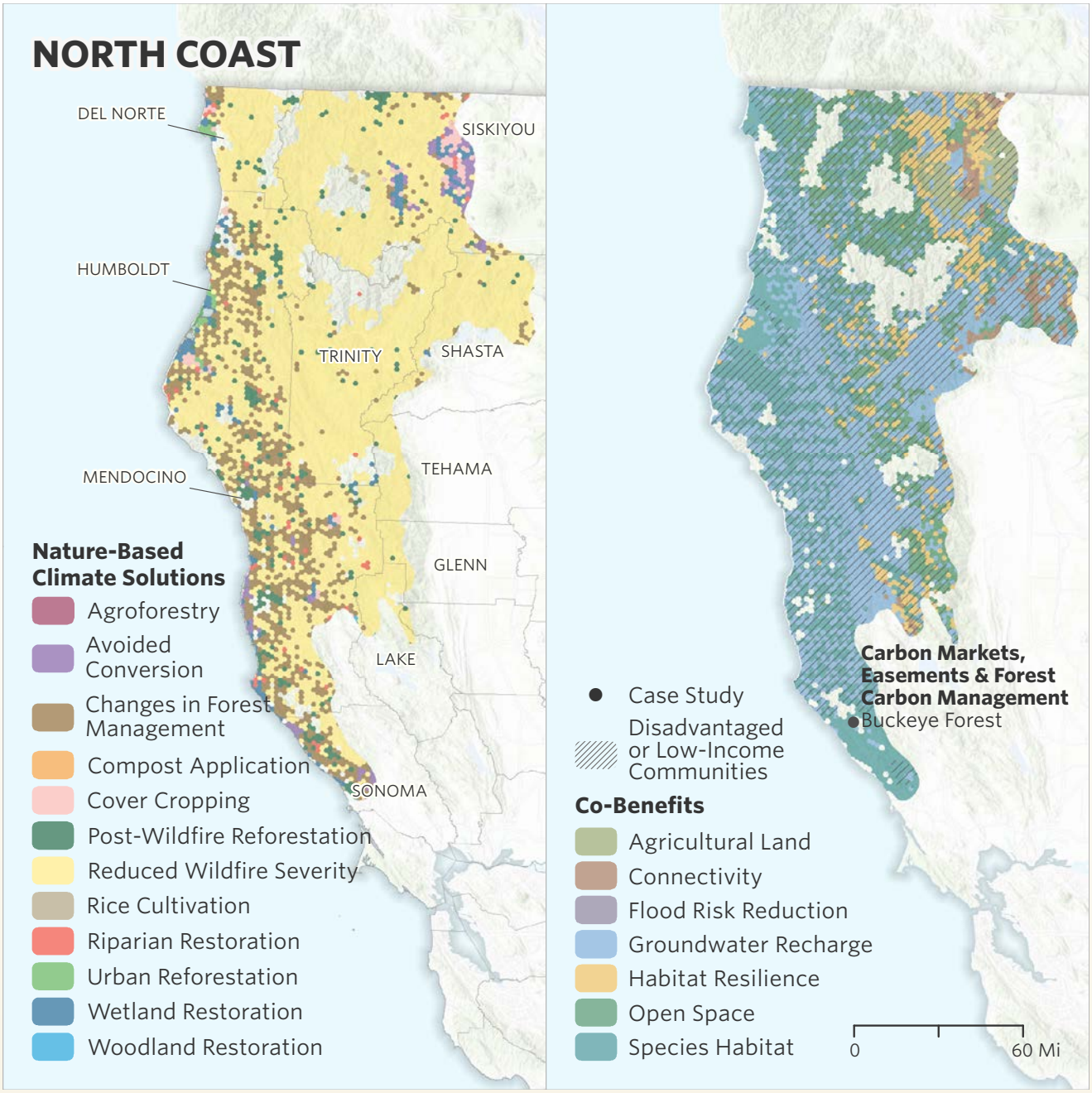


FIGURE 23. Nature-based climate solutions for the North Coast. This region, which is rich in natural resources, is suitable for a wide range of nature-based climate solutions. Although the figure shows a substantial amount of opportunity for reduced wildfire severity, it is worth noting that there is overlap among the nature-based solutions that are mapped here—meaning that the full extent of other opportunities is not shown. The same is true for the co-benefit map on the right, and all other regional opportunity maps in this section. In the two maps, the predominant colors reflect, respectively, the solution and co-benefit with the largest spatial extent, within a 1600-acre hexagon.

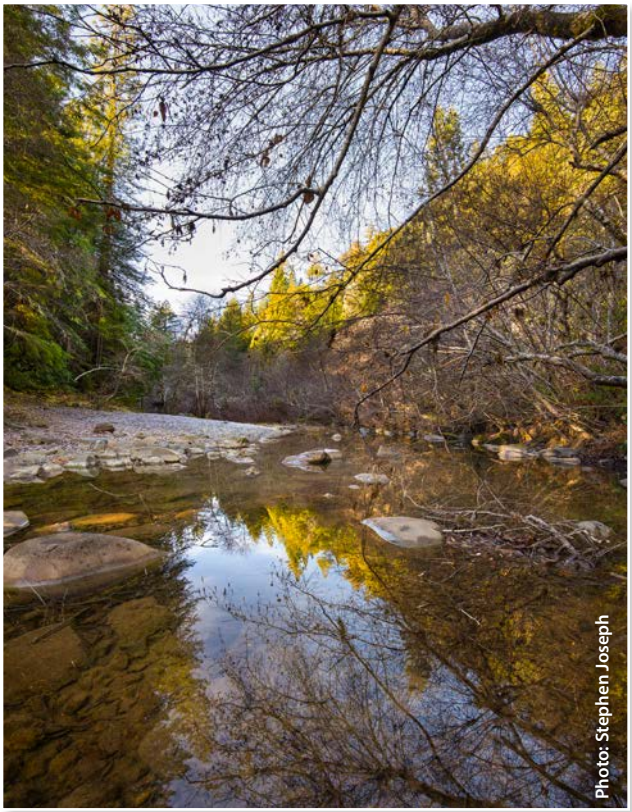


FIGURE 24. The Buckeye Forest, located in Sonoma County, is rich in natural resources.

conversion of 1,670 acres of forestland and 190 acres of grassland. Original planning documents estimated that more than 300,000 trees would be removed. Instead, the property was purchased by The Conservation Fund in partnership with the California Coastal Conservancy. The new landowners entered into a conservation easement (held by Sonoma County Agricultural Preservation and Open Space District) that limits development, excludes vineyard conversion and allows economically and ecologically sustainable forest management, including long-term harvest of forest products.

The project financing included an innovative revenue participation agreement according to which The Conservation Fund developed an offset project involving improved forest management. The project was registered with the California cap-and-trade program and The Conservation Fund agreed with the California Coastal Conservancy to share the offset revenue, minus project expenses. Greenhouse gas emission reductions from the project have averaged about 100,000 tons of carbon dioxide equivalent (CO_2e) annually. From the project's inception in 2013 through 2019, offset sales generated approximately $6.8 million in gross revenues. After project expenses, the Coastal Conservancy received revenue of about $1.85 million through 2019, which is used to support additional conservation activities. The Conservation Fund has received about $1.25 million. The co-benefits associated with this project include enhanced habitat for steelhead trout and water quality (the Gualala River is an impaired water body under the Clean Water Act).

Policy Discussion and Recommendations

The Buckeye Forest project exemplifies the kinds of programs, policy tools and partnerships that, with the right support, could help accelerate changes in forest management—across the region and in other coastal forest areas in the state—to leverage climate and other benefits. Both conservation easements and markets for forest carbon can provide incentives and funding that support changes to, or improvements in, forest management, which in turn can both reduce emissions and sequester more carbon. When combined, these policy mechanisms have the potential to create greater incentives to conserve forestland and manage it for greater carbon storage over time. Furthermore, the combination of both public funds (for the easement) and private funds (from the carbon market) can give the use of public funds greater conservation and climate impact.

Below is an explanation of how these policies and tools can work, as well as recommendations for how the state can make these tools and solutions more effective to leverage impact.

Leverage use of conservation and working forest easements for climate benefits. Easements, which are voluntary agreements that run with the land, can be used as a tool to guide or limit management activities. They can also help increase carbon sequestration across the landscape over time. Landowners are financially compensated for easements and the agreed-upon limitations.

Recommendations. The use of easements as a tool to support GHG reductions and other benefits could be accelerated by the State if it clarified the carbon rights associated with easements, developed a common language that could accompany easements to facilitate greater carbon sequestration over time and dedicated more funding to easement programs at the Wildlife Conservation Board and State conservancies.[20]

Enable more landowner access to carbon markets. Carbon markets,[21] regulatory and voluntary, serve as another financial incentive to landowners to manage

for climate benefits alongside other goals. They can help pay for the opportunity costs of changing management practices to sequester carbon. In California's regulatory GHG emissions trading program (cap-and-trade program), offsets from changes in forest management represent the greatest amount of GHG reductions in the program.

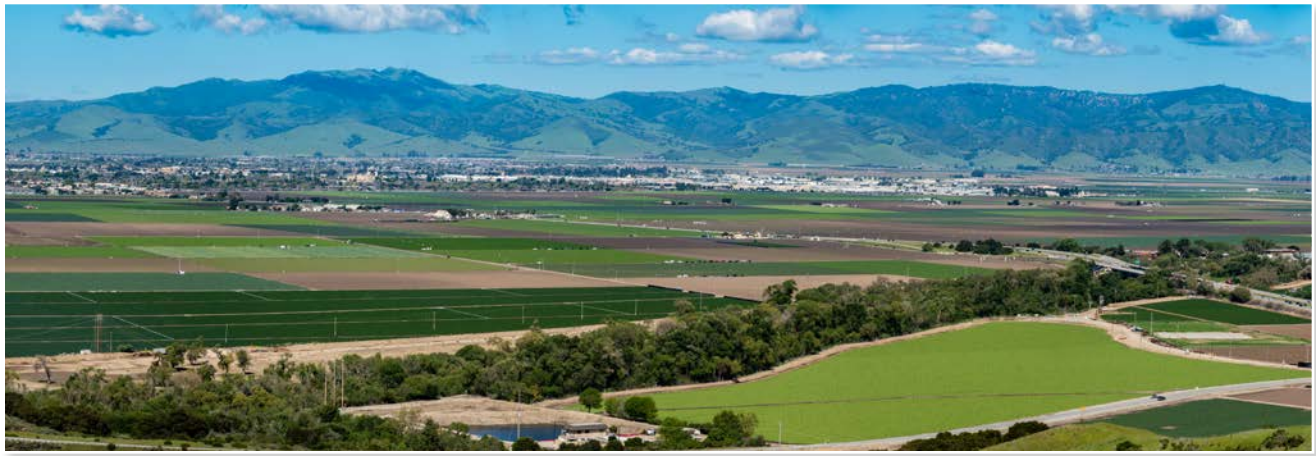
Recommendations. The State could help accelerate GHG reduction through changes in forest management by providing longer-term certainty for the duration of the program as a whole (i.e., extension to 2045 via legislation) and making the program more accessible for smaller forest landowners. Greater involvement from smaller landowners could be facilitated through the adoption of a forest offset protocol that allows smaller landowners to aggregate their projects to help reduce costs. A "catalyst fund," with the use of GGRF funds or bond funding, could also help smaller landowners with initial costs associated with developing an offset project, which are often a barrier. With improvements in remote sensing technologies, CARB could also review ways to reduce monitoring and verification costs.

Facilitate combined use of easements and carbon markets. In some cases, the combined incentives of conservation easements and carbon markets could provide greater motivation for landowners to undertake forest management activities to reduce emissions and sequester more carbon. This innovative combination also provides an opportunity to leverage conservation and climate impacts by making the conservation dollar go farther—similar to the arrangement for the Buckeye Forest, for example, whereby the Coastal Conservancy receives a percentage of the forest offset revenue, which it can reinvest in conservation to achieve even more climate and conservation benefits.

Recommendations. To advance the combined use of conservation easements with carbon markets, the State should clarify technical issues around carbon rights and their ownership and, using the Buckeye Forest as an example, identify how State conservancies could replicate this model elsewhere in California. This could include a review of enabling statutes for other conservancies and easement programs across the state to ensure they have or can get the authorization needed to enter into revenue-sharing agreements related to climate change and the sale of offsets. As stated previously, to reach a broader population of landowners, it would still be important to facilitate the participation of smaller landowners.

FIGURE 25. The Buckeye Forest covers 30 square miles of the Gualala River watershed.

DELTA AND CENTRAL VALLEY



Delta and Central Valley

NBS Reduction Opportunities: rice cultivation, wetland restoration, compost application, agroforestry, cover cropping, nitrogen management, riparian restoration, avoided conversion

Climate Impact Protection: Groundwater recharge, soil moisture, flood attenuation, habitat connectivity and refugia, sea level rise, air quality

County Climate Action: Shasta, Tehama, Butte, Colusa, Yuba, Lake, Nevada, Placer, Sutter, Napa, Solano, Sacramento, Amador, Calaveras, Tuolumne, Stanislaus, Mariposa, Merced, Madera, Fresno, Tulare, Kings, Kern

California Climate Investments: $174.84 million

Case Study Focus: Regional Climate Tools, Williamson Act Update, Sustainable Agricultural Land Conservation Program

California's Central Valley dominates the interior of California. Formed by two smaller valleys that converge to form the expansive Sacramento-San Joaquin Delta region, the Central Valley joins multiple ecological regions that provide habitat for a diverse range of species, including wetland waterfowl[22] and the critically endangered San Joaquin kit fox.

The Central Valley is also the engine that drives California's agricultural food production, providing nearly 10% of all fruits, vegetables, nuts and dairy in the United States alone. However, agricultural production is highly sensitive to the temperature and water changes that accompany climate change. Increasing climate stress, along with rapid urban growth, spurs the conversion of agricultural land to urban uses—increasing GHG emissions while decreasing land for food production and degrading habitat for wildlife.

A once successful program, the Williamson Act, helped preserve more than 17 million of California's 29 million acres of farmland and rangeland. It did so by offering landowners a lower tax rate in exchange for the promise to continue farming their land. The State supported the Act by providing counties with subvention payments to make up for lost tax revenues to local governments. However, in 2009, the State eliminated subvention payments, hindering the ability of many counties, especially small and primarily rural counties, to enter into Williamson Act contracts with landowners (CDC 2020).

While the Central Valley faces a number of challenges that are exacerbated by climate change impacts, the State can help address them through climate policies that integrate nature-based solutions. Based on our analysis, the Central Valley collectively provides opportunities for a wide range of nature-based greenhouse gas reduction solutions, including rice cultivation, wetland restoration, compost application, agroforestry, cover cropping, nitrogen management and avoided

conversion. Such solutions can also deliver a suite of other important benefits, including healthier and more productive soil, groundwater recharge, wildlife habitat and air quality protection, among others.

The discussion below, with Merced County as a case study, offers several policy recommendations that could help address challenges in the Central Valley while also advancing overall state climate change mitigation goals.

Figure 26 shows nature-based climate solutions and corresponding co-benefits available in the Delta and Central Valley. Figure 27 shows suitable acreage for avoided conversion and cover cropping in Merced County, as well as related co-benefits.

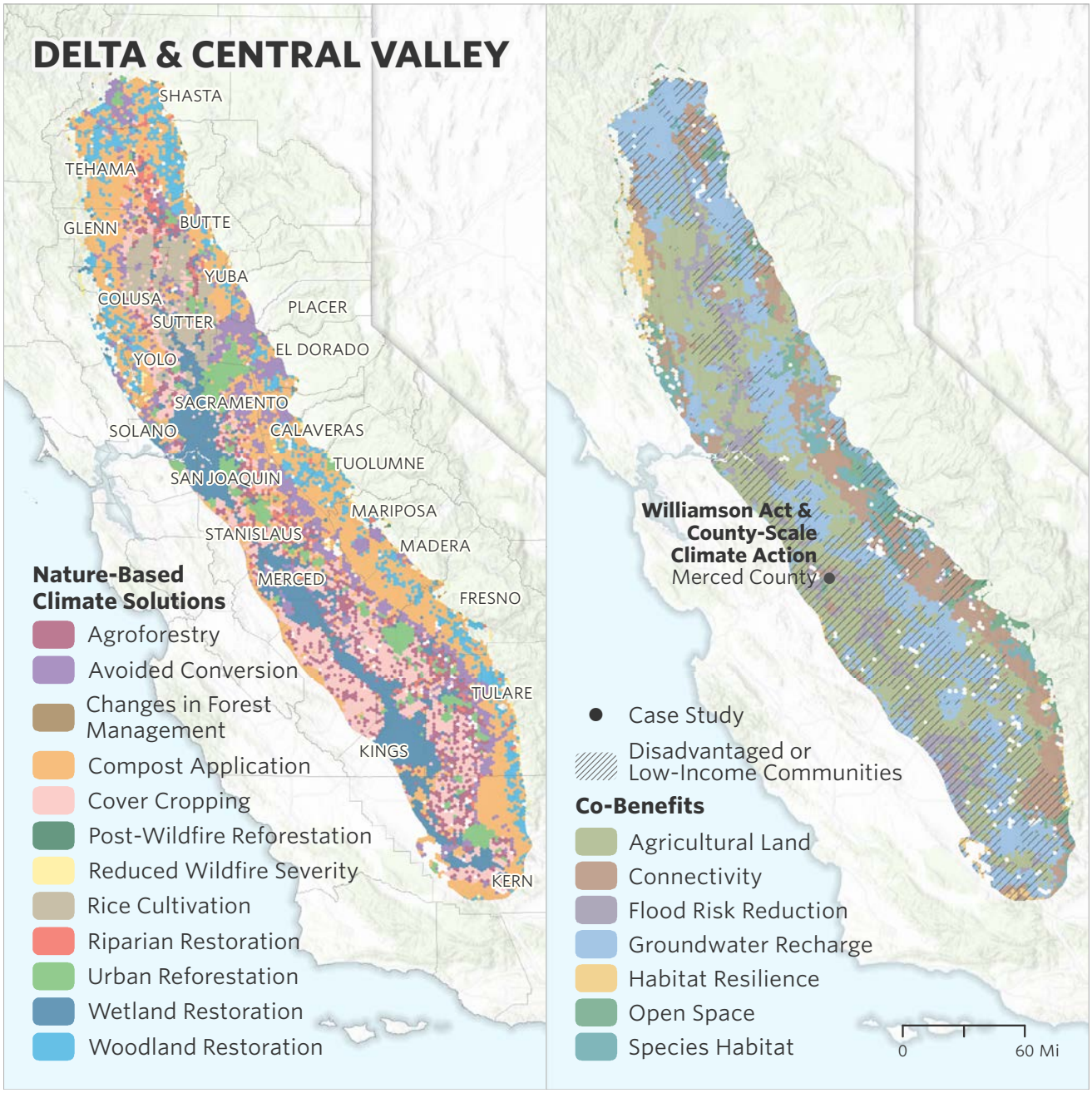


FIGURE 26. Nature-based climate solutions for the Delta and Central Valley. This region is a driver of California's agricultural economy.

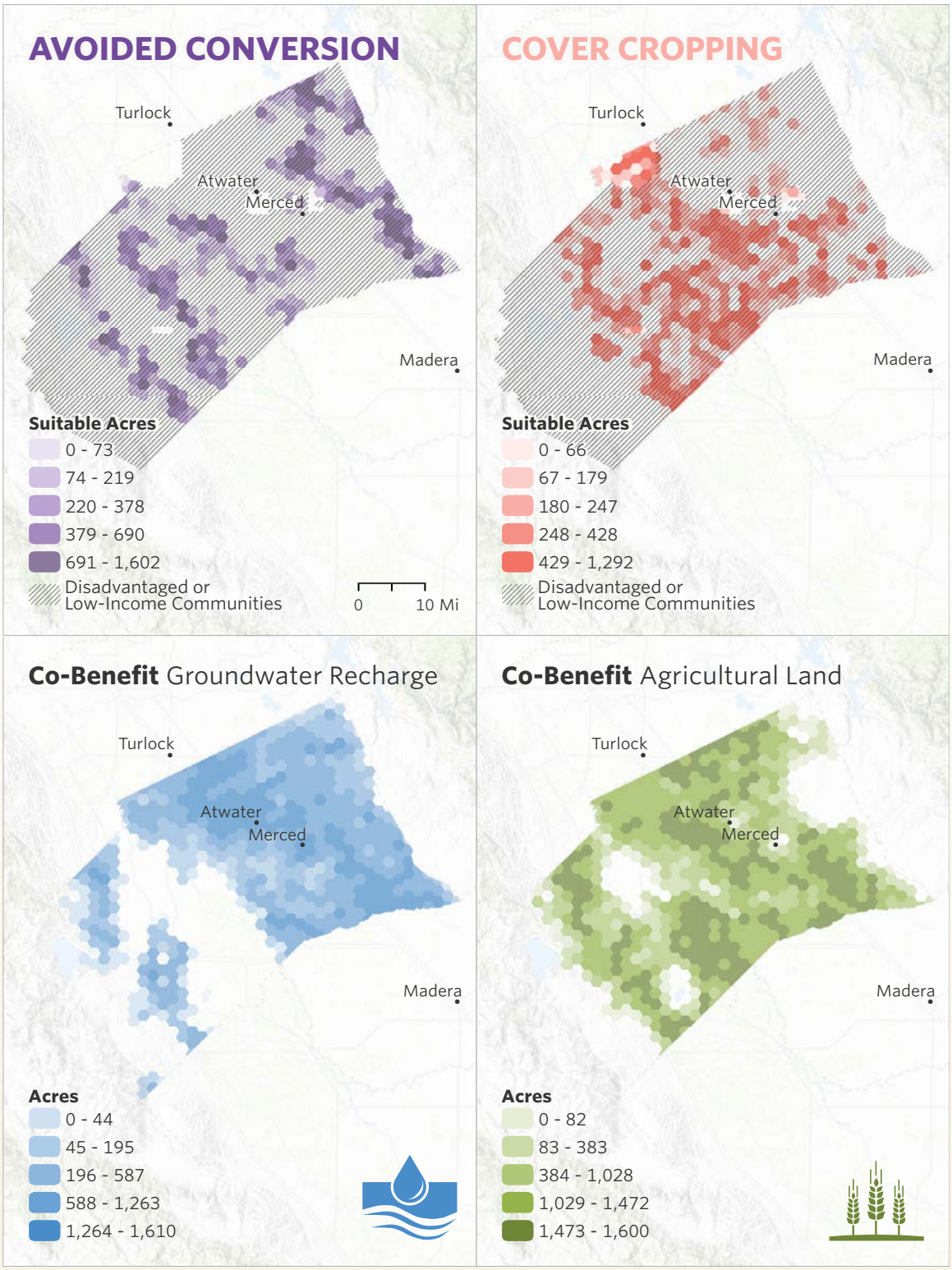


FIGURE 27. Delta and Central Valley case study—Merced County. The top panels show suitable area, in acres, for two nature-based climate solutions (avoided conversion and cover cropping), while the bottom panels showcase related co-benefits. With rapid increases in population and urban growth, Merced County stands to benefit substantially from the co-benefits that accompany nature-based climate solutions.

Merced County: Achieving greenhouse gas reductions at scale through agricultural land management and conservation

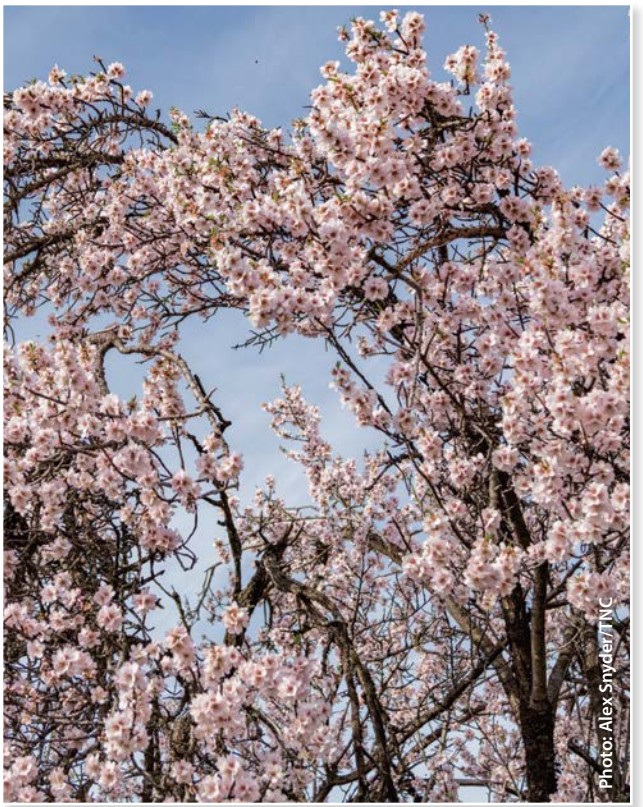
Merced County is located in the heart of the San Joaquin Valley. The majority of the county's land is used for the production of food and fiber. But the amount of land in agricultural use is shrinking as agricultural land is developed and converted to other uses, diminishing the climate and community benefits that natural and working lands provide. At the same time, Merced County's population is projected to increase more than 50% by 2050 (ESB 2016).

With this growth and with increasing climate impacts, the county faces important decisions regarding its land use and management. As of 2009, Merced County had 467,679 acres enrolled in Williamson Act contracts—45% of Merced's agricultural land. However, financial constraints at the State and local level have impacted the county's ability to continue conserving its lands in this way.

Despite these challenges, Merced County has also been assessing its GHG emissions and developing a Climate Action Plan. In a related effort, the County, in collaboration with the DOC and The Nature Conservancy (TNC), participated in a project to assess the potential GHG reductions and co-benefits associated with different land management, restoration and conservation efforts across the county. The result was the development of a countywide GHG accounting framework and decision support tool (TerraCount) that enables local governments, like Merced County, and landowners to assess the GHG reductions and associated co-benefits of various land management and restoration activities across the region at a county and landowner scale.

Initial scenarios modeled with TerraCount suggest that the county could reduce emissions and increase carbon sequestration across its natural and working lands by nearly 40% over a 15-year period through a variety of practices, including planting of hedgerows, mulching, compost application, nitrogen management, riparian restoration and avoided conversion, among other solutions (Nature Conservancy n.d. a). Additional benefits identified in the scenarios included decreased water use, enhanced groundwater recharge and improved air quality and species habitat.

Other counties and regions in California—including Santa Barbara, Mariposa and Sonoma Counties, as well as the San Diego Association of Governments—are using TerraCount to inform their land-use and climate



plans and to integrate nature-based climate solutions into those plans. In 2019, the DOC awarded $950,000 in bond-funded grants to local governments, regional governments and planning organizations to integrate natural and working lands into climate and land-use plans. Of this total, nearly half of the dollars awarded were intended for planning that incorporated TerraCount.

When coupled with capacity building and financial incentives, tools and metrics like those provided by TerraCount can deliver nature-based climate benefits at scale and help address other needs across the Central Valley and elsewhere.

Policy Discussion and Recommendations

In addition to landowners, counties and local governments can play a key role in addressing climate change and using nature-based solutions to support such efforts. The State can be an important partner in these efforts and can accelerate action by providing technical support and incentives. The following are some policy recommendations for State action.

Leverage use of existing climate tools and metrics that support nature-based climate solutions. Computer-based tools like TerraCount enable regional and local jurisdictions to assess and integrate nature-based climate solutions into their land-use and climate

plans, helping both local governments and the State to shape their climate goals in a strategic and cohesive way. These tools and metrics also help to align local climate strategies with other public and environmental goals. In the case of Merced, the use of TerraCount would not only help the County understand the climate benefits associated with different land-use and management strategies but also help it identify strategies that could support groundwater recharge and reduced water consumption, among other things.

Recommendation. The State should increase efforts to support counties and regions in integrating nature-based solutions in their climate action plans, using tools like TerraCount.[23] The DOC and other State agencies should continue to dedicate grant funds, when available, to expand the use of TerraCount. In addition, the State should conduct outreach and provide technical support to counties and regions to enable the use of these tools. To build additional capacity, the DOC and other State agencies should partner with resource conservation districts and University of California Cooperative Extension and graduate schools to train students and specialists to use these tools.

Provide incentives to local governments and landowners to implement nature-based climate solutions. Tools and metrics to build capacity among local governments and regions need to be aligned with the incentives of both local governments and landowners to leverage nature-based climate action across the state.

Recommendations.

- Given the success of the Williamson Act, the Legislature should restore subvention payments and update the program to include land management and conservation activities like cover cropping, nitrogen management and agroforestry, among others, to promote both climate benefits and sustained agricultural and rangeland production. Tools like TerraCount could be used to support implementation by counties and landowners.
- CARB and the DOC should align the use of TerraCount with GGRF programs and investments so that funds from programs like the Sustainable Agricultural Lands Conservation Program can support the implementation of climate action plans that integrate nature-based climate solutions and achieve impact at a larger scale.
- CNRA should support the implementation of low-impact solar or upland habitat restoration on lands retired[24] to help meet SGMA water demand needs. CNRA should provide this support by incentivizing Groundwater Sustainability Agencies to include such projects as a way to create nature-based GHG reductions.

SIERRA NEVADA AND SOUTHERN CASCADES

Sierra Nevada and Southern Cascades

NBS Reduction Opportunities: reduced wildfire severity, avoided conversion, cover cropping, post-wildfire reforestation, riparian restoration, changes in forest management, wetland restoration

Climate Impact Protections: Fire risk reduction, habitat connectivity and refugia, soil moisture retention, flood attenuation, groundwater recharge, air quality

County Climate Action: Modoc, Shasta, Tehama, Plumas, Butte, Yuba, Nevada, Placer, Amador, Alpine, Calaveras, Tuolumne, Mono, Mariposa, Tulare, Inyo

California Climate Investments: $192.1 million

Case Study Focus: State-federal collaboration, permit reform, catalyst fund for new markets

California's Sierra Nevada and Southern Cascade region is a mountainous and heavily forested area, hosting iconic landmarks like Mount Whitney (the highest point in the contiguous United States), Lake Tahoe and Yosemite Falls. More than half the land area in the region is under federal ownership and more than 23 million California residents across the state rely on the region as a source of drinking water (Water Education Foundation 2020). The local economy relies on the region's working landscapes and associated industries like timber production—and also relies heavily on the millions of tourists who visit each year for recreational opportunities like skiing, hiking, biking and camping. To protect this economy, natural resources and forests also need to be sustained.

Our analysis identifies a suite of beneficial nature-based solutions that can help mitigate climate change and support the regional economy. These solutions include changes in forest management, avoided conversion, post-wildfire reforestation and reduced wildfire severity, among others. Many benefits are associated with the implementation of these solutions, including groundwater recharge, enhanced air quality, flood risk reduction and habitat resilience and connectivity. Given the significant need to reduce wildfire severity and its associated GHG emissions, the case study in this section focuses on policy recommendations to reduce wildfire severity.

Wildfire severity can be reduced through fuel reduction treatments, which include the thinning of overly dense forests and prescribed burning in forests. These treatments, which entail the removal of overly dense thickets and small trees that exacerbate or fuel fire, can dramatically increase the stability of existing and future stored carbon in forests. Such treatments can ultimately restore a healthier, more diverse forest structure. The current rates of fuel reduction treatments are far below the levels needed to restore forest health, prevent high-severity fires and meet California's climate goals over the long term.

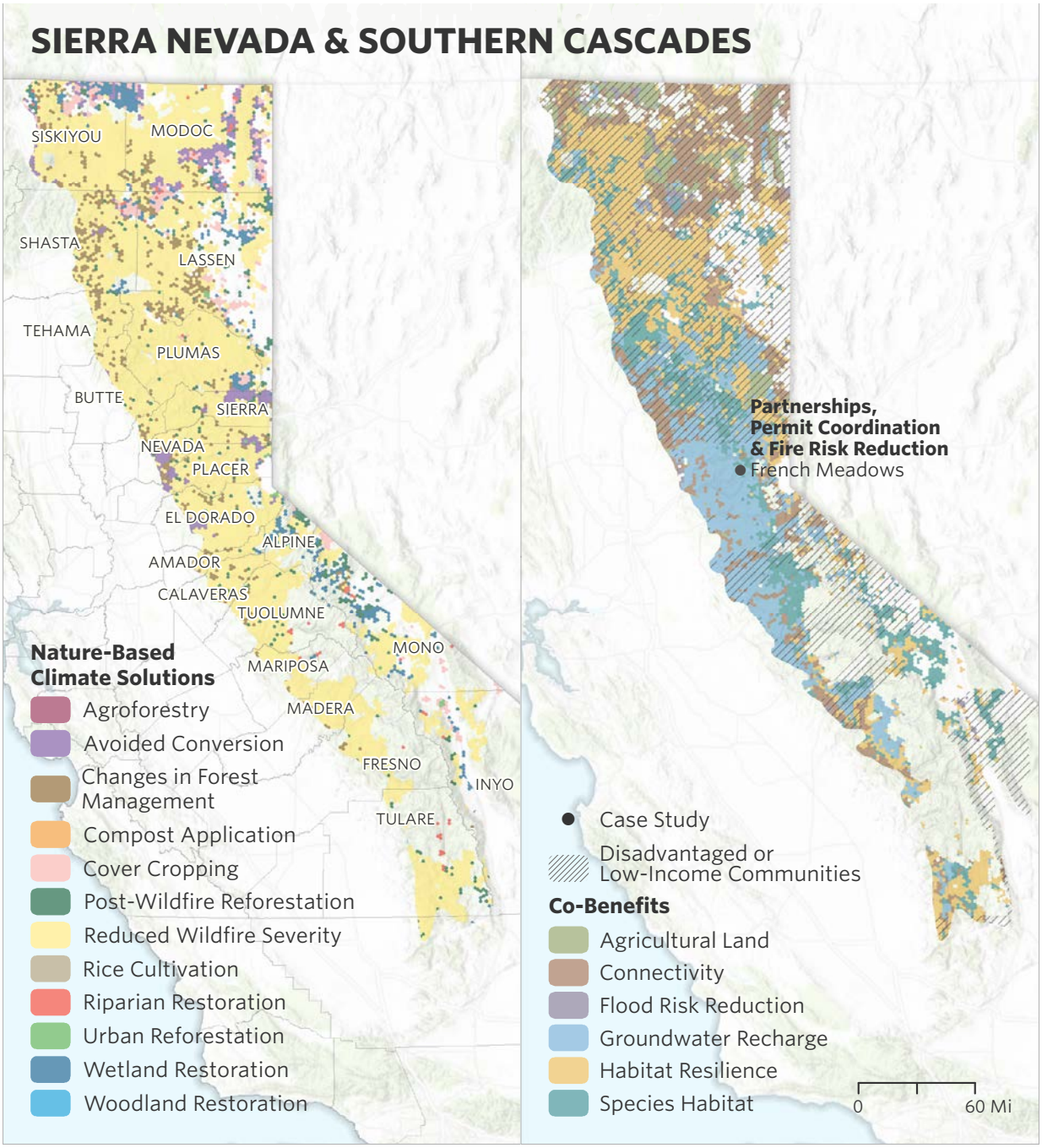


FIGURE 28. Nature-based climate solutions for the Sierra Nevada and Southern Cascades region.

With the diversity of land ownership in the region and dominance of federal land ownership, landscape-level collaboration involving federal and state agencies, nongovernmental organizations and private landowners is vital for achieving the needed pace and scale of forest restoration treatments. The French Meadows Project, detailed below, showcases how this type of collaboration can be enacted to maintain California's forests as a reliable long-term carbon sink while reducing wildfire severity and providing multiple benefits for nature and people.

Figure 28 shows nature-based climate solutions suitable to the Sierra Nevada and southern Cascades, along with corresponding co-benefits.

French Meadows Project, Placer County: A case for multipartner collaboration and permitting coordination to accelerate wildfire risk reduction

While it is well known that healthy forests play a critical role in absorbing carbon and helping to mitigate climate change, the extent to which high-severity wildfire is compromising the role of California's forests as a carbon sink has only recently become clear. Many forests in California's Sierra and Southern Cascade region (as well as the western United States overall) are unhealthy and at serious risk of high-severity wildfire, insect-related mortality and drought; these risks are due in part to fire suppression, past forest management and the impacts of climate change. Forests that were once characterized by large, widely spaced trees and beneficial, low- to moderate-severity fires are now dominated by dense thickets of small and medium-sized trees and brush and are increasingly at risk of destructive, high-severity fires. These unhealthy conditions, combined with the impacts of climate change, are putting the carbon sequestration and storage benefits of forests at significant risk.

The French Meadows project, located in the Sierra Nevada, is a restoration and fuel reduction project that includes 28,000 acres of forestland (figs. 29 and 30). The project was developed to improve the health and resilience of the important municipal watershed surrounding the Hell Hole and French Meadows Reservoirs, which—along with other critical water infrastructure—suffered millions of dollars in damage from the 2014 King Fire. The project also aims to address barriers to increasing the pace and scale of forest restoration work in the Sierra Nevada (Edelson and Hertslet 2019).

The project uses an innovative partnership framework for planning, management and implementation. Approximately 80% of the lands within the project area are federally owned, and the diverse project partnership—which includes the Forest Service, Placer County Water Agency, Placer County, Sierra Nevada Conservancy, American River Conservancy, Sierra Nevada Research Institute and TNC—facilitates

FIGURE 29. The French Meadows Project site, with a view of the French Meadows Reservoir below.

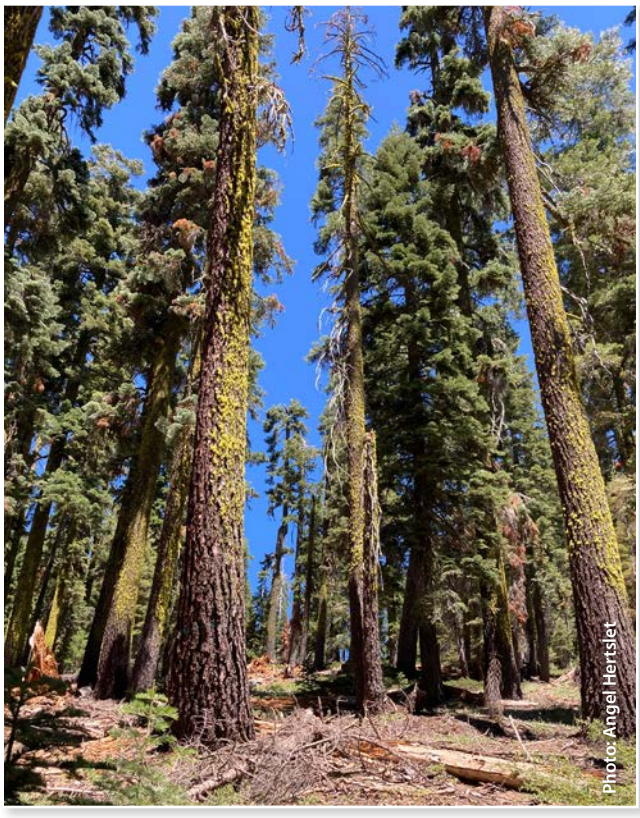


FIGURE 30. The French Meadows Project involves restoration and fuel reduction work on more than 28,000 acres of forest land.

restoration activities that span both public and private lands. This "all lands" approach allows restoration work to be addressed on landscape scales and provides unique opportunities to leverage both public and private funds. For the French Meadows project, funding sources included a wide variety of federal, local, state and private sources, including significant investment from the GGRF and downstream water beneficiaries.

The French Meadows project will reduce fuels on approximately 6,000 acres of forestland through mechanical thinning, mastication and hand-thinning. The project will also involve 7,600 acres of prescribed burning, to be managed by the Forest Service and TNC. To implement fuel reduction work on federal lands, Placer County entered into a Master Stewardship Agreement with the Forest Service.[25]

In 2019, more than 1,000 acres were treated with the help of local contractors. As a result, more than 3 million board feet of wood were delivered to local mills and more than 4,200 green tons of biomass went to local renewable energy facilities, where 2,656 megawatt-hours of renewable energy were generated (meeting the annual electricity needs of 330 households). Revenues from the sale of wood products and biomass are used to partially fund the project. An additional 600 acres were prepared for prescribed burning in 2020.

Policy Discussion and Recommendations

With an area that is representative of conditions in the broader central and northern Sierra Nevada, the French Meadows project serves as a pilot that can help to inform forest restoration and State policy on much larger scales. The French Meadows project is an example of a collaborative approach to landscape-scale restoration and management activities—one that helped accelerate permitting processes while providing access to diverse funding sources. Scaling up similar activities across the state will require similar processes that advance 1) better access to substantial funding and 2) continued collaboration with private landowners and the federal government to expedite planning and permitting. Innovative solutions to utilize the woody biomass byproducts that result from fuel treatments will also be needed.

Collaboration and planning across jurisdictions and stakeholders are essential for expediting action. Ecological processes such as forest fires and wildlife habitat do not align with land ownership boundaries, but land management activities—and funding sources—often do. Strategic partnerships allow activities to be implemented across ownership boundaries, on landscape scales, while accessing funding from diverse sources. Additionally, as the French Meadows project illustrates, partnerships can substantially increase project pace while reducing barriers related to planning and permitting. For federal lands, project agreements that utilize Stewardship Authority or Good Neighbor Authority provide mechanisms to help facilitate collaborations that involve federally owned lands.

Recommendation. Given the extent of federally owned land in California, the CNRA and State Legislature should accelerate ecological forest restoration[26] and fire risk reduction on larger scales by expanding their use of Stewardship Authority and Good Neighbor Authority, with staff support and enhanced funding. The State of California and the Forest Service recently developed a memorandum of understanding regarding forest stewardship (the Agreement for Shared Stewardship of California's Forest and Rangelands); it provides a basis to scale up active forest management in a coordinated management framework.

Improve the permitting process for forest restoration. Costs related to project planning and permitting are often a significant barrier to increasing the pace and scale of forest restoration activities and fire risk reduction activities. While some important steps have been taken to address this issue, additional adjustments to the State's permitting requirements could help reduce this barrier and facilitate the implementation of larger-scale projects.[27]

Recommendations. The CNRA should accelerate landscape-scale forest restoration and management by reducing duplication, costs and time delays that are associated with the regulatory review process for forest restoration and prescribed burning. This includes expediting or exempting CEQA if a project has already been approved through the National Environmental Policy Act (NEPA). Additionally, continued financial support for and expanded use of the California Vegetative Treatment Program (CalVTP) will enable a more streamlined approach to prescribed fire and forest health projects on a landscape scale.

Continue to prioritize funding and develop new incentives for forest restoration and reduced fire risk. Due to the extent of unhealthy forest conditions across California, a substantial amount of funding is needed to increase both the pace and scale of forest restoration and management activities.

Recommendations.

- The Legislature and Administration should, at a minimum, maintain and preferably increase their funding commitment of $200 million per year for forest health and fire risk reduction from GGRF.
- The Agreement for Shared Stewardship of California's Forest and Rangelands should be used to secure a commitment by the federal government to match California's funding commitment in order to reduce wildfire risk in the state.[28]
- The State should develop new competitive grant programs (i.e., a climate catalyst fund) and pursue public-private partnerships to help catalyze the development of new markets for woody biomass, including small-scale renewable energy with a low impact on air quality.

BAY AREA AND CENTRAL COAST

Bay Area and Central Coast

NBS Reduction Opportunities: avoided conversion, wetland restoration, compost application, urban reforestation, riparian restoration, woodland restoration, cover cropping, changes in forest management

Climate Impact Protection: Habitat connectivity and support, flood attenuation, groundwater recharge, soil moisture retention, urban heat island reduction, sea level rise

County Climate Action: Lake, Sonoma, Napa, Marin, Solano, Alameda, Stanislaus, San Mateo, Santa Clara, Santa Cruz, Monterey, Contra Costa, San Luis Obispo, Kern, Kings, Fresno, San Benito, Merced

California Climate Investments: $115.16 million

Case Study Focus: Leveraging conservation with transportation funds, permit reform, state hazard mitigation guidelines and funding

The San Francisco Bay Area and Central Coast is a populous area that hosts a variety of habitats and vegetation, ranging from coastal prairie scrub to redwoods and valley oaks—and from rolling hills inland to coastal mountains that lead to the ocean. The region is also known for its highly productive farmland and wetlands, which are a key stopover for migratory birds traveling between Mexico and Alaska. Based on our analysis, a variety of nature-based GHG reduction solutions could be applied to this region, including wetland restoration (and wetland conservation), urban reforestation, compost application and avoided conversion, among others. in addition to reducing emissions and sequestering carbon, these solutions would have the added benefits of protecting against sea level rise, flooding and wildfires, reducing urban heat island effects, and providing habitat for migratory birds and access to open space.

A variety of state policies could support these solutions and accelerate action in this region, as highlighted in the adjacent map (fig. 31). Below are two policy case studies for the region that showcase the kinds of programs and policies that can help leverage the climate benefits of wetland restoration and wetland conservation, among other solutions, which could be replicated or scaled up with State involvement.

Dotson Family Marsh: Conserving and restoring Bay Area coastal wetlands with transportation and conservation funding

The Dotson Family Marsh (fig. 32) is a 238-acre regional wetland located along the San Pablo Bay in Richmond. Acquired by East Bay Regional Parks in 2009, it extends the southern boundary of Point Pinole Regional Shoreline. The Marsh is undergoing the restoration of 60 acres of wetland and 90 acres of coastal prairie and is identified as a Priority Conservation Area. Priority Conservation Areas, or PCAs, are regionally significant open-space areas that face development pressure and

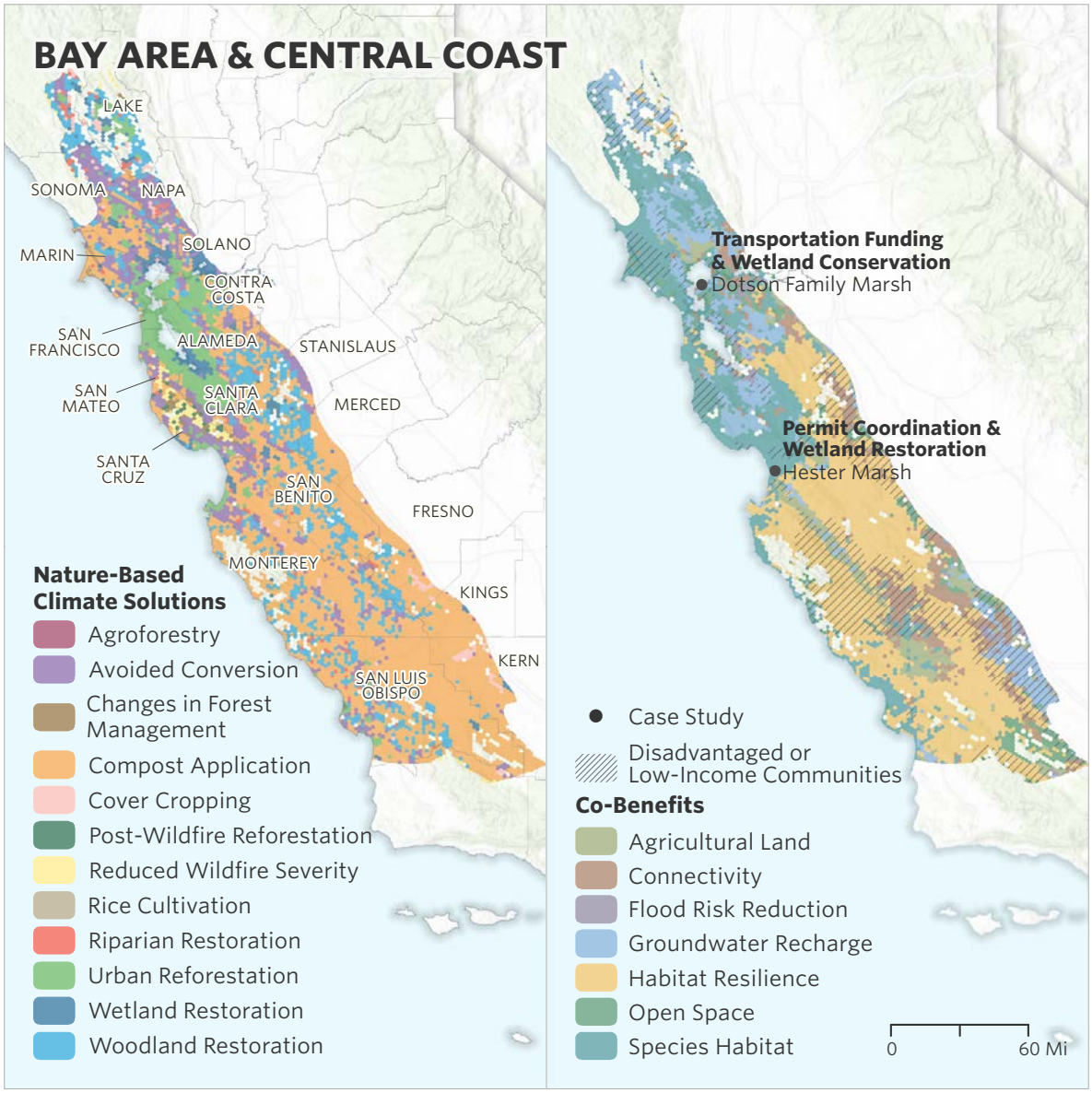


FIGURE 31. Nature-based climate solutions for the Bay Area and Central Coast region. A wide range of nature-based climate solutions is suitable for this region.

are designated for preservation though local government consensus in the nine-county Bay Area (ABAG 2020). The conservation and restoration activities at Dotson Family Marsh help to avoid carbon dioxide emissions associated with conversion to other uses, and the Marsh also sequesters more carbon from the atmosphere through additional restoration. The restoration efforts here and elsewhere around the Bay are also expected to mitigate future damage from rising sea levels and flooding. A variety of funding sources have been used to preserve and restore the Marsh. For the purposes of this case study, the focus is on the One Bay Area Grant (OBAG) program and its innovative approach of leveraging federal transportation funds to support land conservation and restoration.

The OBAG program at the Metropolitan Transportation Commission (MTC), an innovative model and partnership, is intended to support land conservation and restoration in the Bay Area and is consistent with designated PCAs. The OBAG program provides funding to cities, counties, park districts, utility districts and other agencies and nonprofits to acquire, enhance

FIGURE 32. The Dotson Family Marsh, as seen from above, is a 238-acre regional wetland located along the San Pablo Bay in Richmond East Bay Regional Park District.

or improve PCAs in the Bay Area. While not designed specifically for climate change mitigation, the OBAG program supports land restoration and conservation activities that are highlighted in our analysis as providing significant GHG mitigation opportunities for the Bay Area and Central Coast. The program was initiated in 2013 and aligns with the Plan Bay Area initiative established by the Association of Bay Area Governments (ABAG) and the MTC in 2007. Plan Bay Area is a plan outlining the future of the nine-county San Francisco Bay Area, with a focus on transportation, the economy, the environment and housing.

Through the OBAG program, MTC—in partnership with the California Coastal Conservancy—is leveraging funds for land conservation and restoration with federal transportation funds. Over the past seven years, MTC has awarded $24.3 million in grant money to support the conservation and restoration of 44 projects in the Bay Area,[29] including the Dotson Family Marsh.[30] During the first round of grants, transportation funds needed to be spent primarily on trails and public access for projects, and the California Coastal Conservancy provided bond money (from Proposition 40) to help pay for conservation and restoration efforts. For the second round of OBAG grant funds, awarded in 2019, MTC was able to create more flexible funding by exchanging transportation funds for local funds that could be granted directly for land conservation, restoration and fee acquisition.

Policy Discussion and Recommendations:

The OBAG program leverages nature-based climate strategies in the region by combining both transportation and conservation dollars to support Plan Bay Area's stated goals and objectives and its adopted growth strategy. In spite of the strong relationship among transportation infrastructure, development and land conversion, transportation funds have typically not been invested in land conservation and restoration, which makes this program innovative. The program also has the potential to be scaled up in the region and elsewhere across the state. Using OBAG as a guide, the following are recommendations that, with State support, could help achieve even greater climate impact at scale.

Enable regional transportation agencies to replicate and implement programs like OBAG. By sharing lessons learned from the OBAG program and building capacity, the State could help MTC and other regional transportation agencies develop programs similar to the OBAG program and leverage nature-based climate solutions and GHG reductions.

Recommendations.

- The California Strategic Growth Council (SGC) should convene a series of discussions with regional transportation agencies across the state to help them develop plans, such as greenprints,[31] and grant programs similar to OBAG that support regional and state climate goals by integrating land conservation, restoration and urban greening activities to reduce emissions and sequester carbon. Other regional transportation agencies are seeking to implement land conservation strategies to support their regional plans.
- As CARB and other state agencies, like CNRA, identify nature-based climate solutions to support carbon neutrality, they should provide common metrics and guidance that can be used by regional transportation agencies and local governments to estimate and track the GHG benefits associated with land restoration and conservation.
- During the next Plan Bay Area update (for 2050), the State could provide support to MTC/ABAG to develop a vision or climate goal for Bay Area PCA lands, which could complement state efforts to reach carbon neutrality and serve as a model for other regions.

Facilitate greater use and coordination of transportation funds to support land conservation and restoration. In addition to setting aside more funding, the OBAG program and others like it could more readily dedicate transportation funds to land conservation and restoration if federal policy were adjusted and if State bond funds were coordinated with such programs.

Recommendations.

- As with the coordinated use and investment of bond funds between the California State Coastal Conservancy and MTC, CalTrans could coordinate with MTC and other regional transportation agencies and target the use of bond funds (e.g., SB 1) to complement and support land conservation and restoration to meet regional and State climate and environmental goals.
- During the next reauthorization of the federal Fixing America's Surface Transportation Act, the State could support amending the language to permit use of land restoration and conservation activities to support transportation agencies' and communities' goals, among them to help mitigate and constrain transportation impacts and GHGs. Amended language would give MTC and other regional transportation agencies more flexible options for use of transportation funds.

Hester Marsh restoration: Restoring tidal wetlands for climate protection—and a case for improving the permitting process

The Hester Marsh Restoration project, led by the Tidal Wetland Program at the Elkhorn Slough National Estuarine Research Reserve, includes the restoration of 120 acres of tidal marsh in the Elkhorn Slough of Monterey Bay. Elkhorn Slough is one of California's largest estuaries and is the largest salt marsh south of San Francisco Bay. It is also important habitat for migratory birds, invertebrates, fish, marine mammals and other wildlife. The Slough is surrounded by development and highly productive agricultural land.

The Hester Marsh Project (fig. 33) is designed to reduce carbon dioxide in the atmosphere through carbon sequestration.[32] In addition to GHG reductions, the wetland restoration will achieve multiple benefits,

FIGURE 33. The Hester Marsh Restoration Project involves the restoration of 120 acres of tidal marsh in the Elkhorn Slough of Monterey Bay.

including an increase in the extent of tidal marsh to protect against climate impacts, such as sea level rise and flooding, and improve surface water quality and sea otter habitat.

The Elkhorn Slough and its restoration have been funded through a wide variety of State, federal and private funding sources. Half of the Hester Marsh restoration is being funded with GGRF money through the California Department of Fish and Wildlife (CDFW) Wetlands Restoration for GHG Reduction Program. Additional funding for the restoration comes from a variety of sources, including the U.S. Fish and Wildlife Service and California's Department of Water Resources (DWR), State Coastal Conservancy, Wildlife Conservation Board (WCB) and Ocean Protection Council.

There is potential for more wetland restoration across the region and the state, with roughly 158,000 available acres along the Central Coast alone and nearly 1.9 million acres of coastal and inland wetlands across the state. Yet, to restore wetlands more quickly and to scale up efforts to meet the pace and scale of climate change, the State will need to develop partnerships to undertake a number of efforts. Continued funding—and ultimately, increased funding—through existing programs will be needed. However, the State can also support nonmonetary efforts that will help accelerate action to conserve and restore wetlands to reduce carbon dioxide and achieve other important benefits. Using the Hester Marsh restoration as a case study, these recommendations are described below.

Policy Discussion and Recommendations

To accelerate and expand action for wetland restoration, several ideas flow from this project that can support and expedite wetland restoration along the California coast, and as well as in other areas in the state, like the Sacramento-San Joaquin Delta.

Improve CEQA permitting process and agency/government coordination. While marsh restoration in Elkhorn Slough (and in particular, Hester Marsh) has been a success, it took more than three years to obtain the permits necessary to begin restoration of Hester Marsh. Improving this complex process would save limited time and money.

Recommendations.

- As part of its "cutting the green tape initiative" (CNRA 2020), the Legislature and Administration should improve the permitting process for wetland restoration and develop permitting exemptions or waivers for wetland restoration with appropriate safeguards.
- The Administration could, via executive order, provide overarching direction and guidance to the different State agencies (e.g., CDFW, State Water Resources Control Board, California Coastal Commission) and counties involved in the wetland restoration permitting process to provide for coordinated approval in a more timely manner.

Facilitate new markets and incentives for the climate benefits of wetland restoration and conservation. As with the carbon market that has been developed for forest conservation and restoration, the State should facilitate a market for wetland restoration. Accounting protocols have been developed by voluntary climate registries that could be vetted by the State for approval and use in the State's GHG emissions trading program (cap-and-trade program).

Recommendation. CARB should facilitate the development of new markets for wetland restoration by reviewing and adopting a wetland restoration protocol as part of the state's cap-and-trade program.

Elevate and fund wetland restoration and nature-based solutions in pre-disaster mitigation efforts. Wetlands and nature in general provide climate protection value beyond carbon sequestration. Intact wetlands can protect communities and wildlife from climate impacts, such as sea level rise and flooding, thereby acting as pre-disaster mitigation. One of the goals of the Hester Marsh restoration is to restore and elevate the wetlands so they can provide protection from sea level rise.

Recommendations.

- The California Office of Emergency Services should include wetland conservation, alongside other nature-based solutions, in the State hazard mitigation plan. It should also prioritize investment of its new hazard mitigation funds—from the Building Resilient Infrastructure and Communities (BRIC) program—in the preservation and restoration of wetlands.
- As bond funds or funding from the GGRF become available, the Legislature and Administration should ensure that sufficient funds are appropriated to CDFW and the WCB for wetland restoration and conservation easements to restore and preserve wetlands for climate and other important benefits.

SOUTHERN CALIFORNIA

Southern California

NBS Reduction Opportunities: urban reforestation, avoided conversion, wetland restoration, compost application, reduced wildfire severity, cover cropping

Climate Impact Protections: Reduced urban heat islands, habitat connectivity and refugia, groundwater recharge, flood attenuation, soil moisture retention, sea level rise, fire risk reduction, air quality

County Climate Action: Santa Barbara, Ventura, Kern, Los Angeles, San Diego, Imperial, Riverside, San Bernardino

California Climate Investments: $127.73 million

Case Study Focus: Urban tree-canopy gap goal, expanding urban forestry with utility programs, updating CEQA GHG guidance, Sustainable Communities Strategies

Southern California is known for its sandy beaches and moderate climate along the coast and its valleys and desert in the inland area. The region holds extremely high levels of species biodiversity, as well as the greatest number of threatened and endangered species in the state. It is also highly urbanized, hosting the two largest cities along the West Coast: Los Angeles and San Diego. The dense population centers and their proximity to sensitive natural areas present unique challenges and opportunities for the region.

Based on our analysis, a variety of nature-based solutions could achieve and support GHG reductions across the region (fig. 34). These solutions include urban reforestation, avoided conversion, reduced wildfire severity and compost application, among others. Aside from GHG reductions, implementation of these actions would also achieve critical public benefits such as air quality protection, reduced urban heat island effect, groundwater recharge, enhanced soil productivity and species habitat connectivity. State policies and programs that could support and accelerate these solutions include CAL FIRE's Healthy Forests and Community Forestry Programs and CDFA's Healthy Soils Program, as well as conservation easement programs (e.g., WCB, California State Coastal Conservancy, Rivers and Mountain Conservancy, Coachella Valley Mountain Conservancy and so on).

In addition to these State programs, other partnerships and policies could, with State support, also accelerate GHG reductions through nature-based solutions. Below are two policy case studies for the region, which showcase the kinds of programs and policies that can support two prominent nature-based climate mitigation opportunities for the region: avoided conversion and urban reforestation.

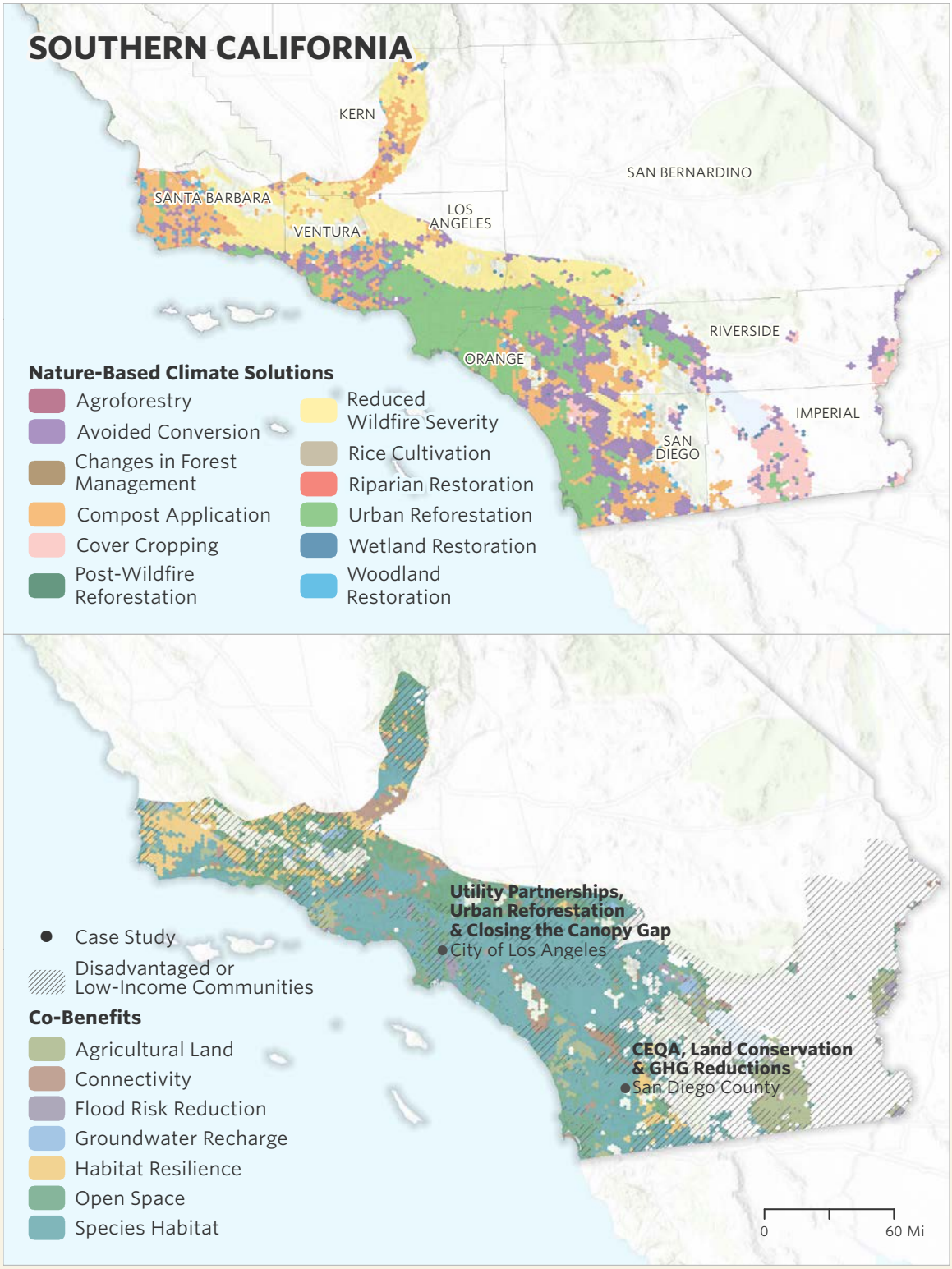


FIGURE 34. The Southern California region. As a highly biodiverse—but also highly urban—area, Southern California offers unique opportunities to implement nature-based climate solutions.

San Diego County: An opportunity to reduce GHG emissions through complementary land conservation and VMT reduction strategies

Avoiding or minimizing the conversion of land to urbanization is one of the nature-based climate mitigation opportunities identified for San Diego County (fig. 35). San Diego County is the most biologically diverse county in the continental United States. The county has a strong history of conservation and was one of the first California counties to adopt, in the 1990s, a Habitat Conservation Plan (HCP) and Natural Communities Conservation Plan (NCCP). These are mitigation plans under the Federal Endangered Species Act designed to guide development in a manner that minimizes negative impacts to wildlife species and habitat. To support implementation of the NCCP, the San Diego Association of Governments (SANDAG) has also developed a robust Regional Environmental Mitigation Program (EMP) that has preserved just under 9,000 acres to offset transportation projects' impacts on sensitive species and habitats before the projects are developed. Since the adoption of the NCCP and development of the associated EMP, thousands of acres have been preserved in the county.

Despite these conservation accomplishments, the plans have been unable to fully deter housing and development growth into important habitat and open-space areas. Development growth of this kind can undermine not only habitat conservation efforts but also the climate change mitigation benefits associated with land conservation—as well as efforts, pursuant to State laws like SB 375, to constrain VMT. (SB 375 directs regional transportation agencies like SANDAG to reduce transportation emissions.) The challenge of meeting both local and State climate change mitigation and conservation goals is exacerbated by the lack of alignment between CEQA guidelines for GHG mitigation and the goals of SB 375. (The challenge, of course, is an opportunity as well.)

The County of San Diego has twice attempted to adopt Climate Action Plans (CAPs, a required mitigation measure of the County's General Plan). However, the two CAPs have been challenged by multiple organizations and have not been upheld in courts (Sierra Club et al. v. County of San Diego 2020; Smith 2020; Anderson 2018). A contested issue with the most recent proposed CAP is how the County would mitigate GHG emissions, especially by planned new developments that are being sought as changes, or amendments, to the approved General Plan. The proposed CAP would allow for new development, through General Plan amendments, to mitigate associated GHG emissions through offsets outside the county—raising legal questions about consistency with the County's General Plan and overall climate goals. The GHG mitigation guidelines under CEQA permit GHG emissions to be offset by activities without geographic constraints (GOPR 2020). Furthermore, offset activities may come from sectors other than transportation, like land restoration and conservation (carbon sequestration). As a result, a broad interpretation of CEQA GHG mitigation guidelines can lead to, if not support, mitigation efforts outside the region, and even the state—and therefore can hinder efforts to reduce emissions locally and within the state.

The recent court case setting aside the County's latest proposed CAP highlights this discrepancy and ongoing challenge (see Sierra Club et al. v. County of San Diego 2020). While courts can play a role in reconciling this policy conflict, the policy inconsistency presents an opportunity for the State to align these policies in a way that can optimize goals to reduce emissions from both transportation and natural and working lands in a way that also optimizes local benefits.

Policy Discussion and Recommendations

The following recommendations would advance emission reductions from land conversion and development by fostering greater alignment between CEQA and SB 375—and by encouraging more integrated land-use planning that elevates land conservation while helping achieve reduction goals for transportation.

Revise CEQA's GHG mitigation guidelines. CEQA's GHG guidelines can be revised to align and optimize State goals to reduce emissions from transportation and land conversion, helping both the State and local communities meet their climate goals while meeting other important needs.

Recommendation. The Office of Planning and Research should initiate a process to revise the CEQA GHG guidelines. Revisions should include 1) the requirement that project proponents evaluate the GHG emission impacts associated with the conversion of natural and working lands and 2) the provision of a GHG mitigation hierarchy that prioritizes GHG mitigation locally (e.g., transportation and land carbon emissions).

Implement a pilot project. The State should support a pilot project to demonstrate how CEQA GHG mitigation can support an integrated approach to land conservation and efforts to constrain VMT.

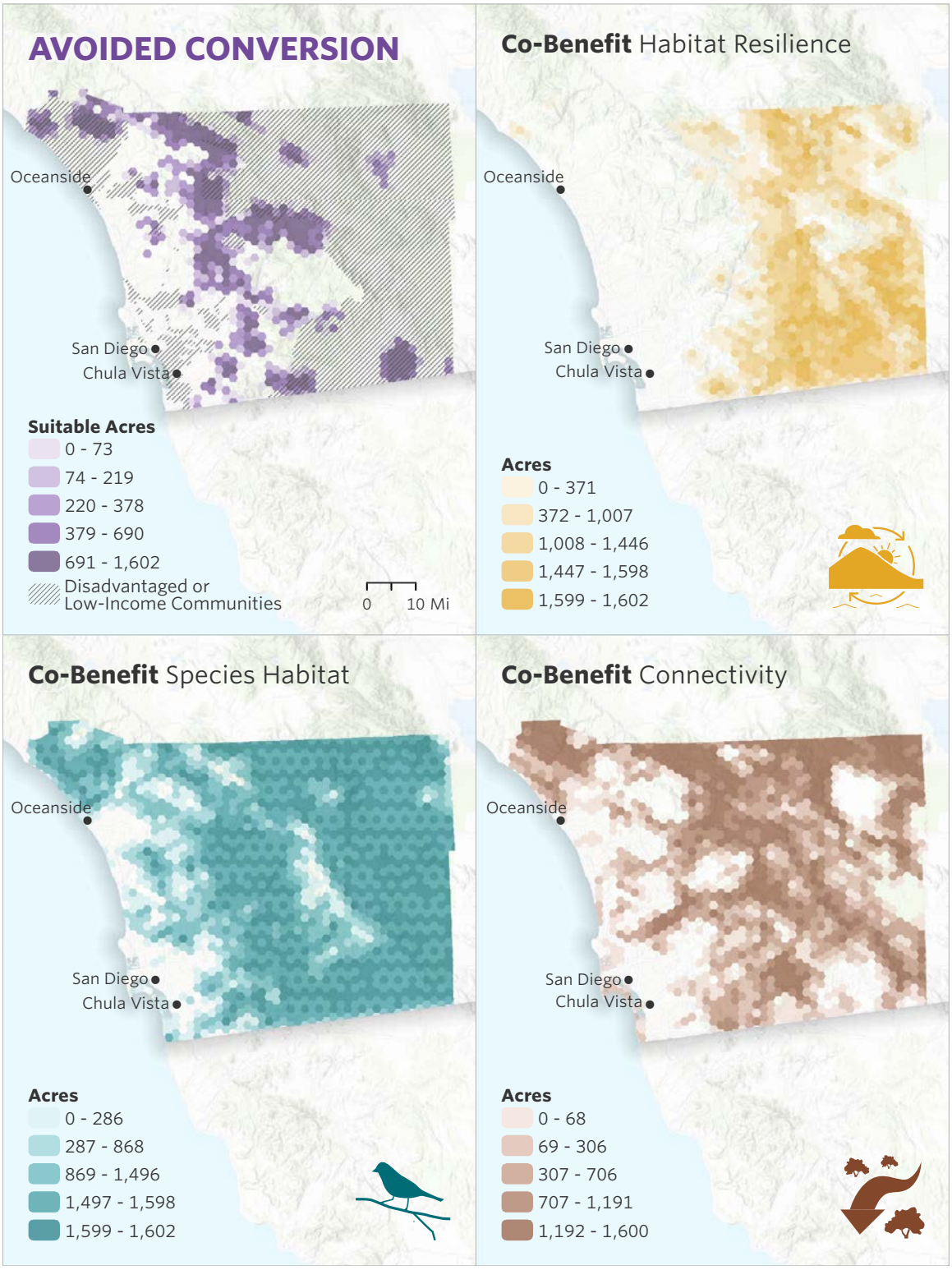


FIGURE 35. Southern California case study—San Diego County. In the top left panel, suitable areas for avoided conversion are overlaid with disadvantaged and low-income communities (hashed area), showing the potential for impacting priority populations. Corresponding co-benefits, shown in the other three panels, offer benefits that support regional biodiversity, in addition to the GHG reductions discussed in the case study.

Recommendation. The SGC, in collaboration with CNRA, CARB, San Diego County and SANDAG, should support a CEQA/SB 375 pilot in San Diego County and other parts of the state whereby CEQA mitigation funds are used to integrate regional land conservation as a strategy to support both land-based and transportation-related GHG emission reductions. The pilot could include an in-lieu fee program or a regional VMT credit strategy[33] whereby a credit system would be established that ties preservation of working and natural lands, including wildlife corridors, to reducing development in the most impactful places and that thereby reduces VMT and carbon dioxide emissions.

Update SB 375. SB 375 legislation could be updated to more effectively integrate and prioritize the conservation of natural and working lands as a companion strategy to the reduction of transportation emissions.

Recommendation. The Legislature should revise SB 375 or develop companion legislation to elevate natural and working land conservation as a complementary strategy to help reduce VMT and transportation emissions. Greenprints, HCPs, NCCPs, priority conservation lands and high carbon-storing lands can serve as constraint layers to inform adopted growth strategies.

Build capacity among counties and metropolitan planning organizations (MPOs) to integrate natural and working lands as part of overall climate and land-use plans. An obstacle to efforts by counties and regional transportation agencies to integrate natural and working lands into climate and land-use plans has been a lack of expertise, data and tools.

Recommendation. The SGC, in collaboration with CARB, should provide guidance, tools, funding and technical support to counties and regional MPOs to integrate land conservation and management in climate action plans and Sustainable Community Strategies. State agencies, nonprofits and other institutions have developed tools, conservation plans and greenprints—such as TerraCount, UrbanFootprint and Bay Area Greenprint. NCCPs that can serve as models and build capacity are being used in San Diego and other areas of the state. Greater State support for the coordinated use of these resources could accelerate their use and impact.

Identify the emission reduction synergies between land conservation and VMT reduction. Several recent analyses highlight the synergistic climate benefits that occur when planning integrates land conservation with transportation and development (Jackson et al. 2012; Nature Conservancy n.d. a).

Recommendation. In the next California Climate Change Scoping Plan (to be adopted by 2022), CARB, the SGC and CNRA should identify land conservation efforts as a strategy to sequester carbon and reduce GHG emissions attributable to land conversion/urbanization, as well as to constrain VMT-related emissions. The Climate Change Scoping Plan should also elaborate on the use of transfer of development rights as a strategy to reduce VMT and land conversion and related credits.

City of Los Angeles: Closing the tree-canopy gap across communities and leveraging impact with utilities

The City of Los Angeles, with approximately 4 million people, is the second-most populous city in the United States (behind New York City). While heavily populated (World Population Review 2020), it is also unique as it sits within a biodiversity hotspot with more than 150 threatened and endangered species and high levels of native biodiversity (UCLA Grand Challenges 2020). Based on our analysis, a variety of nature-based climate mitigation solutions are applicable to this region, including urban reforestation (figs. 36 and 37) and avoided conversion, along with fire risk reduction and other

FIGURE 36. Closing the gap between tree cover and income will help to mitigate climate change while providing communities with multiple public health benefits.

FIGURE 37. The City of Los Angeles has been working with a number of partners, including the nonprofit City Plants and the Los Angeles Department of Water and Power, to achieve a bold urban reforestation goal.

benefits. Implementation of these solutions would not only help reduce emissions and sequester carbon but would also help address problems surrounding air quality, extreme heat and public health, maintain biodiversity and species habitat and promote energy efficiency. For the purposes of this case study, the focus is on urban reforestation and the City's climate goal to close the urban tree-canopy gap (fig. 38) across communities, with support from the City's local utility.

In 2019, Los Angeles Mayor Eric Garcetti released a Green New Deal that includes a goal for the City to be carbon neutral by 2050 (Los Angeles 2019). The Plan includes a variety of actions across sectors to achieve this goal, ranging from accelerated renewable energy goals to emission-free buildings by 2050. The Plan also includes a goal to plant 90,000 trees citywide by the end of 2021 and to increase tree canopy by 50% by 2028 in low-income, high-need areas. To achieve this urban reforestation goal, the City has been utilizing many partners, including City Plants and the Los Angeles Department of Water and Power (LADWP). LADWP has been a long-time funder of tree-planting initiatives in Los Angeles, and is funding more than half of the reforestation in this effort, because a key part of its interest in urban reforestation is promoting energy efficiency. Other funding for the City's effort has come from State programs such as the SGC Transformative Climate Communities Program, CAL FIRE's Urban and Community Forestry Program and CNRA's Urban Greening Program and Environmental Enhancement and Mitigation Program. As of May 2020, 31,500 trees have been planted (first trees were planted in 2019).

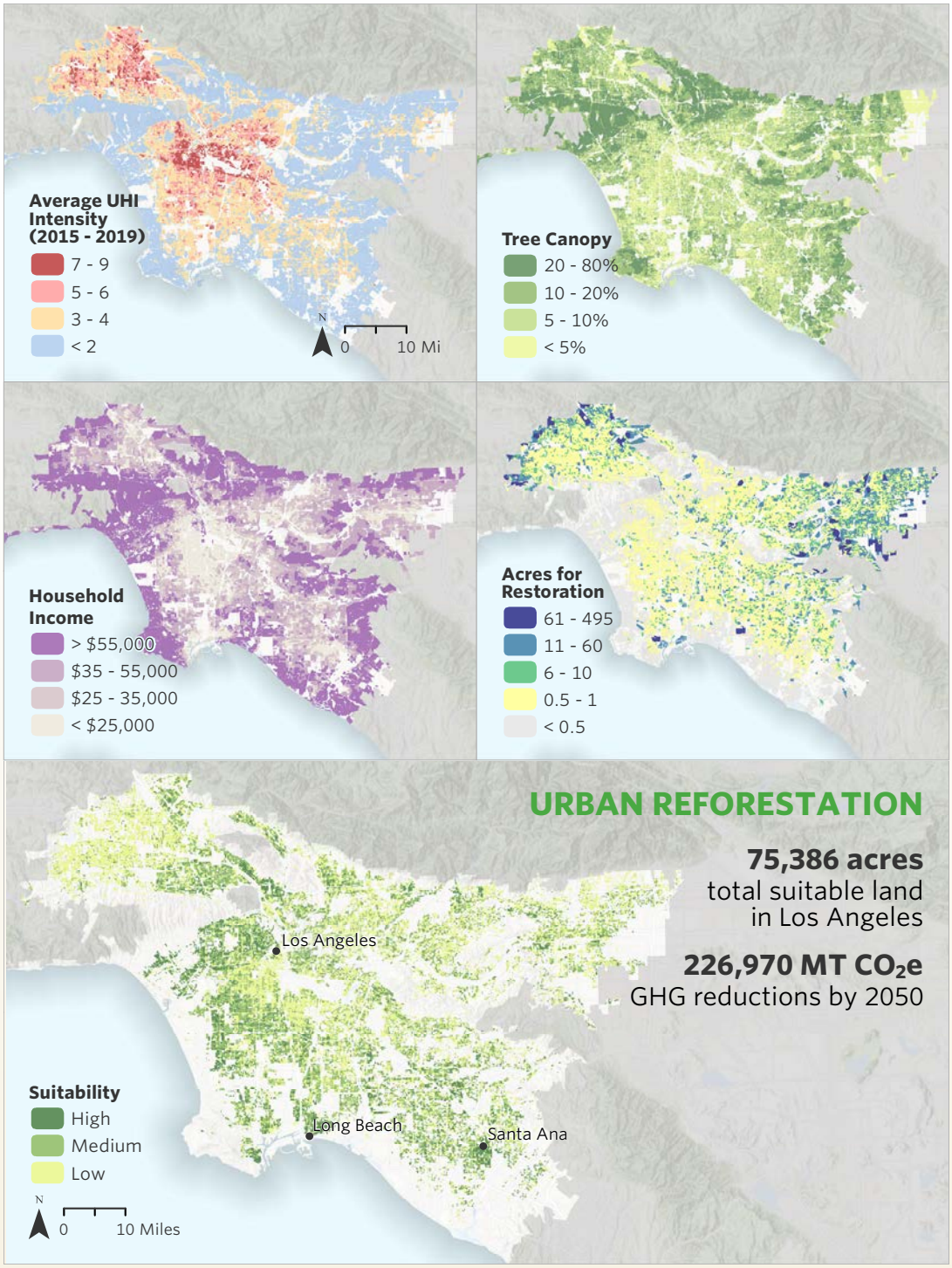


FIGURE 38. Climate change is expected to intensify Urban Heat Island (UHI) effects that disproportionately impact disadvantaged and low-income neighborhoods. This analysis shows that UHI effects are more pronounced in areas with fewer trees – areas that are correlated with lower income levels. In identifying suitable areas for Urban Reforestation, our analysis paints a path forward for addressing tree cover inequity between high- and low-income neighborhoods – or "closing the tree canopy gap" – while reducing greenhouse gas emissions, providing health benefits for underserved communities and reducing UHI effects. Partnerships between the State, local governments, and utility companies are one approach to strategically closing the tree gap. Visit tinyurl.com/closing-treegap to explore the data further.

Policy Discussion and Recommendations

Using L.A.'s Green New Deal and urban reforestation initiative as a case study, several State recommendations emerge for overcoming barriers and accelerating urban reforestation in the region and elsewhere in the state.

Leverage funding for urban reforestation and tree maintenance through partnerships with utilities. The City of Los Angeles is able to augment urban reforestation funding from the State by partnering (through City Plants) with LADWP, thereby extending its impact and its ability to reforest across the city. (The Sacramento Municipal Utility District has a similar tree-planting program.) The State should explore options to support local governments and partner with utilities around the state—electric, water and, potentially, sanitation districts—to leverage funding for urban reforestation and maintenance. Such initiatives would not only sequester carbon but also achieve energy efficiency and catch stormwater runoff.

Recommendation. CNRA, in partnership with CAL FIRE, the California Energy Commission and CARB, should convene discussions with utilities, water districts and local governments around the state to identify how respective funds can be distributed or coordinated in a manner that can accelerate urban reforestation around the state for climate mitigation and multiple benefits.

Launch a statewide initiative to close the tree-canopy gap in underserved communities. Analysis for Los Angeles and other areas across California shows a significant correlation between tree canopy cover and income, with lower-income communities having less tree canopy and higher-income communities having more canopy cover. Closing this gap will help mitigate climate change and also help protect public health in communities that may be hardest hit by climate impacts. [34]

Recommendation. The California Office of Planning and Research, in collaboration with the California Department of Public Health, CAL FIRE, the State Insurance Commissioner and CARB, should launch an effort to identify a goal to help reduce the tree-canopy gap in underserved neighborhoods across the state to support climate and health benefits.

Elevate urban reforestation and recovery and align guidelines across relevant state programs. A barrier to funding urban reforestation efforts is inconsistent requirements across State grant programs. The inconsistency extends to varying prioritization of urban forestry in planning grants and restrictions on use of funds for essential tree recovery, maintenance and technical guidance (e.g., standardized GHG accounting tools).

Recommendations. CAL FIRE should convene a process with other state agencies (e.g., CNRA, SGC, CARB, the Department of Housing and Community Development and Caltrans) to better align grant funding guidelines for urban reforestation and urban forestry solutions—and to consistently elevate urban reforestation and tree recovery as priorities across the programs. Programs include CAL FIRE's Urban and Community Forestry Program, CNRA's Urban Greening Program and Environmental Enhancement and Mitigation Programs and SGC's Affordable Housing and Sustainable Communities and Transformative Climate Communities Programs.

Photo: Ian Shive

IV. Conclusion and Summary Recommendations

This report builds on scientific analyses and a growing body of work that consistently underscore the critical need to include natural and working lands in California's climate goals. Without more explicit action and funding to support expanded stewardship, conservation and restoration of these resources in climate policy, Californians risk falling short of their collective goals to address climate change and secure the many additional benefits that nature-based climate solutions provide.

While increased funding and investment in these resources are fundamental, the State should also pursue key nonmonetary policy pathways and partnerships to accelerate action and to achieve climate benefits at scale. Based on this report and its case studies, the State should undertake the following actions:

- Identify and communicate concise near-, medium- and long-term climate goals for California's natural and working lands, including specific goals for disadvantaged and low-income communities
- Elevate natural and working lands (and their climate benefits) across State grant programs, including those that do not typically focus on natural resources, including health, transportation, housing and other land-use planning programs
- Reduce permitting barriers to natural resource restoration in areas such as wetland restoration and reduced wildfire severity; also, reduce associated barriers that involve agency coordination
- Advance greater funding coordination across State, federal and local governments and private entities
- Align State programs and their guidelines to consistently account for the collective climate benefits of natural and working lands and the climate impacts from their loss—as well as to reduce guideline inconsistencies
- Accelerate outreach and provide technical support to grantees and use existing tools, universities and University of California Cooperative Extension specialists to build capacity to assess the climate benefits of natural and working lands
- Include more experts in ecology, land use and ecosystem and climate health in government decision-making bodies (boards, committees, oversight groups and so on)
- Expand public outreach and education regarding the connections between the climate benefits of natural and working lands and healthy food, community safety and public health

As with all climate change work, more research, pilot projects and analyses can and should be conducted to maintain progress and improve our understanding in this field. However, such work should not stand in the way of the immediate action that is needed to help minimize climate impacts to our communities and leverage the significant and near-term opportunities that our natural and working lands offer to restore the health of our climate and achieve carbon neutrality.

Photo: Mark Godfrey, TNC

References

(ABAG) Association of Bay Area Governments. 2020. PCA—priority conservation areas. https://abag.ca.gov/our-work/land-use/pca-priority-conservation-areas

Anderson, A. 2018. Court rejects San Diego County's climate action plan again. KPBS, Dec. 26. https://www.kpbs.org/news/2018/dec/26/court-rejects-san-diego-countys-climate-action-pla/

Baker, S. E., J. K. Stolaroff, G. Peridas, S. H. Pang, H. M. Goldstein, F. R. Lucci, W. Li, E. W. Slessarev, J. Pett-Ridge, F. J. Ryerson, J. L. Wagoner, W. Kirkendall, R. D. Aines, D. L. Sanchez, B. Cabiyo, J. Baker, S. McCoy, S. Uden, R. Runnebaum, J. Wilcox, P. C. Psarras, H. Pilorgé, N. McQueen, D. Maynard, and C. McCormick. 2019. Getting to neutral: options for negative carbon emissions in California. Lawrence Livermore National Laboratory. LLNL-TR-796100. https://doi.org/10.2172/1597217

Berkeley Law. 2020. Project climate. https://www.law.berkeley.edu/research/clee/research/climate/projectclimate/

(CAL FIRE) California Department of Forestry and Fire Protection. 2020. Urban and Community Forestry. https://www.fire.ca.gov/programs/resource-management/resource-protection-improvement/urban-community-forestry/

California Climate Investments. 2020. Cap-and-trade dollars at work. http://www.caclimateinvestments.ca.gov/

California Water Boards. 2019. California Water Board adopts statewide wetland definition and procedures, April 2. https://www.waterboards.ca.gov/press_room/press_releases/2019/pr04022019_swrcb_dredge_fill.pdf

Cameron, D. R., D. C. Marvin, J. M. Remucal, and M. C. Passero. 2017. Ecosystem management and land conservation can substantially contribute to California's climate mitigation goals. Proceedings of the National Academy of Sciences 114(48):12833-12838. https://doi.org/10.1073/pnas.1707811114

(CARB) California Air Resources Board. 2017. California's 2017 climate change scoping plan. https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf

(CARB) California Air Resources Board. 2018. 2018 progress report: California's Sustainable Communities and Climate Protection Act. https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf

(CARB) California Air Resources Board. 2019a. California Greenhouse Gas Emissions for 2000 to 2017: Trends of Emissions and Other Indicators. https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf

(CARB) California Air Resources Board. 2019b. Draft California 2030 Natural and Working Lands Climate Change Implementation Plan. 2019. https://ww2.arb.ca.gov/resources/documents/nwl-implementation-draft

(CARB) California Air Resources Board. 2020. Cap-and-trade program. https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program

(CDC) California Department of Conservation. 2020. Williamson Act Program Overview. https://www.conservation.ca.gov/dlrp/wa/Pages/wa_overview.aspx

(CDFA) California Department of Food and Agriculture. 2019. Agricultural statistics review, 2018-2019. https://www.cdfa.ca.gov/statistics/PDFs/2018-2019AgReportnass.pdf

(CNRA) California Natural Resources Agency. 2020. Cutting the green tape. https://resources.ca.gov/Initiatives/Cutting-the-Green-Tape

(CWQMC) California Water Quality Monitoring Council. 2013. How much wetland area has California lost? https://www.mywaterquality.ca.gov/eco_health/wetlands/extent/loss.shtml

(DOD/EPA) Department of Defense/Environmental Protection Agency. 2019. Definition of "waters of the United States"—Recodification of pre-existing rules. Federal Register 84(204):56626-56671. https://www.epa.gov/sites/production/files/2019-09/documents/wotus_rin-2040-af74_final_frn_prepub2.pdf

(DOD/EPA) Department of Defense/Environmental Protection Agency. 2020. The navigable waters protection rule: definition of "waters of the United States." Federal Register 85(77):22250-22342. https://www.epa.gov/sites/production/files/2020-01/documents/navigable_waters_protection_rule_prepbulication.pdf

Edelson, D., and A. Hertslet. 2019. Restoring forests through partnership: Lessons learned from the French Meadows Project. https://www.scienceforconservation.org/products/restoring-forests-through-partnership

(ESB) Eberhardt School of Business Center for Business and Policy Research. 2016. Merced County forecast summary. http://www.mcagov.org/DocumentCenter/View/855/Merced-2016-Forecast-Summary_Final?bidId=

Fargione, J. E., S. Bassett, T. Boucher, S. D. Bridgham, R. T. Conant, S. C. Cook-Patton, P. W. Ellis, A. Falcucci, J. W. Fourqurean, T. Gopalakrishna, H. Gu, B. Henderson, M. D. Hurteau, K. D. Kroeger, T. Kroeger, T. J. Lark, S. M. Leavitt, G. Lomax, R. I. McDonald, J. P. Megonigal, D. A. Miteva, C. J. Richardson, J. Sanderman, D. Shoch, S. A. Spawn, J. W. Veldman, C. A. Williams, P. B. Woodbury, C. Zganjar, M. Baranski, P. Elias, R. A. Houghton, E. Landis, E. McGlynn, W. H. Schlesinger, J. V. Siikamaki, A. E. Sutton-Grier. and B. W. Griscom. 2018. Natural climate solutions for the United States. Science Advances 4(11):1-14. https://doi.org/10.1126/sciadv.aat1869

Ghabbour, E. A., G. Davies, T. Misiewicz, R. A. Alami, E. M. Askounas, N. P. Cuozzo, A. J. Filice, J. M. Haskell, A. K. Moy, A. C. Roach, and J. Shade. 2017. National comparison of the total and sequestered organic matter contents of conventional and organic farm soils. Advances in Agronomy 146:1-35. https://doi.org/10.1016/bs.agron.2017.07.003

Gonzalez, P., J. J. Battles, B. M. Collins, R. Robards, and D. S. Saah. 2015. Aboveground live carbon stock changes of California wildland ecosystems, 2001-2010. Forest Ecology and Management 348:68-77. https://doi.org/10.1016/j.foreco.2015.03.040

(GOPR) Governor's Office of Planning and Research. 2020. CEQA and climate change. https://www.opr.ca.gov/ceqa/climate-change.html

Griscom, B. W., J. Adams, P. W. Ellis, R. A. Houghton, G. Lomax, D. A. Miteva, W. H. Schlesinger, D. Shoch, J. V. Siikamäki, P. Smith, P. Woodbury, C. Zganjar, A. Blackman, J. Campari, R. T. Conant, C. Delgado, P. Elias, T. Gopalakrishna, M. R. Hamsik, M. Herrero, J. Kiesecker, E. Landis, L. Laestadius, S. M. Leavitt, S. Minnemeyer, S. Polasky, P. Potapov, F. E. Putz, J. Sanderman, M. Silvius, E. Wollenberg, and J. Fargione. 2017. Natural climate solutions. Proceedings of the National Academy of Sciences of the United States of America 114(44):11645-11650. https://doi.org/10.1073/pnas.1710465114

Hartwig, N. L., and H. U. Ammon. 2002. Cover crops and living mulches. Weed Science 50(6): 688-699. https://www.jstor.org/stable/4046641

(IPCC) Intergovernmental Panel on Climate Change. 2013. Carbon and other biogeochemical cycles. In T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds., Climate Change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK, and New York City. https://doi.org/10.1017/CBO9781107415324.015

(IPCC) Intergovernmental Panel on Climate Change. 2018. Summary for policymakers. In: V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, eds., Global Warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

Jackson, L., V. R. Haden, A. Hollander, H. Lee, M. Lubell, V. Mehta, T. O'Geen, M. T. Niles, J. Perlman, D. Purkey, W. Salas, D. Sumner, M. Tomuta, M. Dempsey, S. Wheeler. 2012. Agricultural mitigation and adaptation to climate change in Yolo County, CA. California Energy Commission Project 500-09-009. https://core.ac.uk/download/pdf/51067404.pdf

Los Angeles. 2019. Mayor Garcetti launches L.A.'s Green New Deal, April 29. https://www.lamayor.org/mayor-garcetti-launches-la%E2%80%99s-green-new-deal

Macdonald, E., R., Sanders, and A. Anderson. 2009. Performance measures for complete, green streets: a proposal for urban arterials in California. UC Transportation Center. https://dot.ca.gov/-/media/dot-media/programs/design/documents/complete-streets-performance-measures-a11y.pdf

Martin, P. L. 2016. How many workers are employed in California agriculture? California Agriculture 71(1):30-34. https://doi.org/10.3733/ca.2016a0011

Marvin, D.C., D. R. Cameron, E., Nelson, A. Plantinga, J. Breck, G. Sencan, and M. Passero. 2018. Toward a carbon neutral California: economic and climate benefits of land use interventions. San Francisco: Next 10. https://www.next10.org/publications/land-carbon

Millman, E. 2020. An instrument maker is building guitars out of highway trees. Rolling Stone, April 24. https://www.rollingstone.com/pro/features/taylor-guitars-highway-trees-989888/

Nature Conservancy. n.d. a. Resilient Merced: a county guide to advance climate change mitigation and complementary benefits through land management and conservation. https://maps.conservation.ca.gov/terracount/downloads/ResilientCountiesGuide.pdf

Nature Conservancy. n.d. b. Roadmap for restoration: strategic land restoration in the San Joaquin Valley of California. https://www.scienceforconservation.org/assets/downloads/Roadmap_to_Restoration_policy_brief.pdf

(OEHHA) California Office of Environmental Health Hazard Assessment. 2020. CalEnviroScreen. https://oehha.ca.gov/calenviroscreen

Perry, F. N., C. Kredell, M. E. Perry, and S. Leonard. 2019. California green innovation index. San Francisco: Next 10. https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-final.pdf

Petrescu, A. M. P., A. Lohila, J.-P. Tuovinen, D. D. Baldocchi, A. R. Desai, N. T. Roulet, T. Vesala, A. J. Dolman, W. C. Oechel, B. Marcolla, T. Friborg, J. Rinne, J. H. Matthes, L. Merbold, A. Meijide, G. Kiely, M. Sottocornola, T. Sachs, D. Zona, A. Varlagin, D. Y. F. Lai, E. Veenendaal, F.-J. W. Parmentier, U. Skiba, M. Lund, A. Hensen, J. van Huissteden, L. B. Flanagan, N. J. Shurpali, T. Grünwald, E. R. Humphreys, M. Jackowicz-Korczyński, M. A. Aurela, T. Laurila, C. Grüning, C. A. R. Corradi, A. P. Schrier-Uijl, T. R. Christensen, M. P. Tamstorf, M. Mastepanov, P. J. Martikainen, S. B. Verma, C. Bernhofer, and A. Cescatti. 2015. The uncertain climate footprint of wetlands. Proceedings of the National Academy of Sciences 112(15):4594-4599. https://doi.org/10.1073/pnas.1416267112

Sacramento Tree Foundation. 2020. Urban wood rescue. https://www.urbanwoodrescue.com/

Sierra Club et al. v. County of San Diego. 2020. Court of Appeal, Fourth Appellate District, Division One, State of California. https://oag.ca.gov/system/files/attachments/press-docs/D075478%20Opn%20Cert%20%2800000003%29.pdf

Sleeter, B. M. , D. C. Marvin, D. R. Cameron, P. C. Selmants, A. L. Westerling, J. Kreitler, C. J. Daniel, J. Liu, and T. S. Wilson. 2019. Effects of 21st-century climate, land use, and disturbances on ecosystem carbon balance in California. Global Change Biology 25(10):3334-3353. https://doi.org/10.1111/gcb.14677

Smith, J. E. 2020. Court tosses San Diego climate plan, calls carbon-offset program 'unlawful.' Los Angeles Times, June 17. https://www.latimes.com/california/story/2020-06-17/court-san-diego-carbon-offset-plan

(SMUD) Sacramento Municipal Utility District. 2020. Shading Sacramento. https://www.smud.org/en/Going-Green/Free-Shade-Trees

Swan A., S. A. Williams, K. Brown, A. Chambers, J. Creque, J. Wick, and K. Paustian. 2015. COMET-Planner: carbon and greenhouse gas evaluation for NRCS conservation practice planning. http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf

UCLA Grand Challenges. 2020. Enhancing biodiversity for the City of Los Angeles. https://slaresearch.grandchallenges.ucla.edu/project/enhancing-biodiversity-city-los-angeles

(USDA) U.S. Department of Agriculture. 2019. 2019 state agriculture review: California. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=CALIFORNIA

USDA Forest Service. 2020. Urban and Community Forestry Program. https://www.fs.usda.gov/managing-land/urban-forests/ucf

Water Education Foundation. 2020. California Water 101. https://www.watereducation.org/photo-gallery/california-water-101

World Population Review. 2020. Los Angeles, California, population 2020. https://worldpopulationreview.com/us-cities/los-angeles-ca-population

Wu, G. C., E. Leslie, D. Allen, O. Sawyerr, D. R. Cameron, E. Brand, B. Cohen, M. Ochoa, and A. Olsen. 2019. Power of place: land conservation and clean energy pathways for California. https://www.scienceforconservation.org/assets/downloads/Technical_Report_Power_of_Place.pdf

Photo: Bill Marr, TNC

Appendices

Appendix A: Operationalizing Nature-based Climate Solutions in California—Relevant Policies

Table A-1 is a list of federal and State policies that can serve as levers or pathways to implement nature-based climate activities. This list is not meant to be comprehensive, but rather showcases the diverse array of government entities and programs that can help support broader implementation of nature-based climate solutions across California.

Table A-2 provides links to useful decision support and scenario analysis tools that can help inform regional and local land managers, planners and landowners in addressing climate change through nature-based solutions.

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS)				
Conservation Stewardship Program (CSP)	AC	Program provides financial and technical assistance to encourage producers to maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resource concerns.w	farm bill	Program provides annual payments for adoption of conservation-oriented practices and provisioning of environmental benefits. It uses a conservation measurement tool and provides technical assistance. Eligible for use on many land-use types, this is the largest conservation program in the United States.
Environmental Quality Incentives Program (EQIP)	AC	Program offers farmers and ranchers financial cost-sharing and technical assistance to implement conservation practices on working agricultural land.	farm bill	Financial assistance is available through a general pool and also through special initiatives, which highlight specific practices or natural resources. In FY2018, California was one of the top three states in active and completed contracts, with $120 million in funding.
Conservation Reserve Program (CRP)/ Conservation Reserve Enhancement Program (CREP)	CC, AF, WL, RR, WR	Program provides financial incentives to farmers to remove environmentally sensitive land from agricultural production and to plant species that will improve environmental health and quality.	farm bill	Eligible land must be recognized as "cropland" (including field margins) or "marginal pastureland," according to certain specifications, and the land must be suitable for certain conservation practices.

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), *continued*				
CRP Farmable Wetlands Program (FWP)	WL	The program, a subset of the Conservation Reserve Program, enrolls small, isolated agricultural wetlands for restoration.	farm bill	Eligibility requires lands to have been used for agricultural purposes for a certain time period. As of August 2019, no active FWP contracts existed in California.
CRP Grasslands Program	AC	The program, a subset of the Conservation Reserve Program, provides financial incentives to protect grasslands, including rangeland and pastureland (as well as certain other lands), while maintaining the areas as grazing lands.	farm bill	
Agricultural Conservation Easement Program	AC, WL	Program provides financial and technical assistance through two types of easements: agricultural land easements (limiting nonagricultural uses on productive farm or grasslands) and wetland reserve easements (protecting and restoring wetlands).	farm bill	
Emergency Watershed Protection (EWP)	AC, WL	Program provides technical and financial assistance to reduce hazards in watersheds that have been damaged by natural disasters, including assistance to purchase easements in flood plains that will benefit natural resources (such as wetlands).	farm bill	
Healthy Forests Reserve Program (HFRP)	RW	Program assists landowners in restoring and enhancing forest ecosystems with easement and contract agreements.	farm bill	
Regional Conservation Partnership Program (RCPP)	RW, RC, WL, CC, RR	Program provides financial and technical assistance for multistate or watershed-scale projects. Creates partnership opportunities to target and leverage federal conservation funding for specific areas and resource concerns.	farm bill	Farmers and ranchers do not apply directly for funding. Instead, partner entities submit proposals to NRCS. Farmers and ranchers can apply through NRCS to participate in RCPP-funded projects. Funding can be used to implement conservation activities or as technical assistance. Half of program funds are dedicated to Critical Conservation Areas (CCAs), which include the Sacramento-San Joaquin Delta.
U.S. Department of Agriculture Farm Service Agency (USDA-FSA)				
Emergency Forest Restoration Program (EFRP)	PR	Program provides cost-sharing assistance to private forestland owners to repair and rehabilitate damage caused by a natural disaster on nonindustrial private forestland. Natural disasters include wildfires, floods, drought and other resource-impacting events as defined by the USDA.	farm bill	

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
U.S. Department of Agriculture Forest Service				
Urban and Community Forestry Program	UF	Program provides funding and technical support to state forestry agencies and nonprofit partners to help communities perform tree inventories, prepare management plans and policies and train staff and residents to plant and care for trees.	farm bill	
Federal Emergency Management Agency (FEMA)				
Hazard Mitigation Grant Program	AC, WL, RR	Program provides funding to state, local, tribal and territorial governments so they can rebuild in a way that reduces, or mitigates, future disaster losses following a presidential major disaster declaration.	Robert T. Stafford Disaster Relief and Emergency Assistance Act	Projects may be funded for property acquisition, for developing and adopting hazard mitigation plans and for activities that may reduce the impacts of flood and drought—including flood plain and stream restoration, flood diversion and storage and green infrastructure.
Building Resilient Infrastructure and Communities (BRIC)	AC, WL, RR	Program supports states, local communities, tribes and territories in undertaking hazard mitigation projects, including those that utilize nature-based solutions to reduce risk and produce multiple co-benefits.	Program receives 6% of federal post-disaster grant funding.	
U.S. Department of Defense (DOD)				
Readiness and Environmental Protection Initiative (REPI)	AC	Initiative authorizes the military services (Army, Navy, Marine Corps and Air Force) to enter into agreements with state or local governments and conservation organizations to protect areas of land from development, restore and enhance habitat and monitor biodiversity while supporting defense readiness.	National Defense Authorization Act	Military services are authorized to enter into agreements with state and local governments or private conservation organizations; these agreements allow the service to cost-share the acquisition of conservation or restrictive-use easements and other interests in land from willing sellers.
National Oceanic and Atmospheric Administration (NOAA)				
Coastal and Estuarine Land Conservation Program (CELCP)	AC	Program provides funds to purchase threatened coastal and estuarine lands or obtain conservation easements.	Omnibus Public Land Management Act of 2009	Lands selected for protection are ecologically significant or possess other coastal conservation values (including historic features, scenic views or recreational opportunities).
California Department of Food and Agriculture (CDFA)				
Fertilizer Research and Education Program (FREP)	NM	Program provides grants for research, demonstration and education projects related to the environmentally safe and agronomically sound use and handling of fertilizing materials.	Program is funded through a mill assessment ($0.001 per dollar) on fertilizer sales.	CDFA is in the process of developing a Nutrient Management Plan (NMP) Certification Program within FREP to coordinate with regional entities in training and educating Certified Crop Advisors who can help growers implement NMPs. NMPs are not connected to any existing or dormant programs, but plans must be in place, especially for farms in high-vulnerability areas.

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
California Department of Food and Agriculture (CDFA), *continued*				
Healthy Soils Program (HSP)	CA, CC, AF	Program provides financial assistance for the implementation of conservation management activities that improve soil health, sequester carbon and reduce GHG emissions.	GGRF	
Technical Assistance Grant Program	CA, CC, AF	Program provides hands-on application assistance for CDFA's Climate Smart Agriculture programs, including the Healthy Soils Program.	GGRF	Funds awarded through competitive grant process are distributed to technical assistance providers from Resource Conservation Districts, University of California Cooperative Extension and nonprofit organizations with demonstrated technical expertise.
Wildlife Conservation Board (WCB)				
Ecosystem Restoration on Agricultural Lands	RR, WL, AF	Program provides funding to assist landowners in developing wildlife-friendly practices on their properties that can be sustained and coexist with agricultural operations.	Proposition 84 and other bonds	Eligible activities include habitat restoration, riparian and flood plain restoration, development of wetland areas, establishment of hedgerows and other activities. All activities must occur on privately owned agricultural lands; standard agreements last 25 years.
Rangeland, Grazing Land and Grassland Protection Act of 2002	AC	Program provides conservation easements to protect rangeland, grazing land and grassland.	no current funding source (legacy program from 2002)	no funding left; legacy program from 2002
Land Acquisition Program	AC	Program acquires real property or rights in real property on behalf of CDFW and can also grant funds to other governmental entities or nonprofit organizations to do the same.	bond; Proposition 1E	Land acquisition is a component of all WCB programs.
Climate Adaptation and Resiliency Program	numerous	Program provides grant funds for projects that provide climate adaptation and resilience benefits on California's natural and working lands.	GGRF	Funding is directed toward projects that protect and restore ecosystems on natural and working lands for climate and wildlife benefits. Projects are to provide additional social, economic and environmental co-benefits in addition to reducing GHG emissions. Technical assistance and acquisition of conservation easements are among eligible project types.
Forest Conservation Program	PR, RW	Program provides funding for planning, acquisition and restoration projects in California forests.	Proposition 68	Project examples include meadow restoration, thinning (fuel reduction) and postfire restoration.
Oak Woodland Conservation Program	WR	Program provides funding for projects designed to conserve and restore California's oak woodlands.	no current funding source (legacy program from 2001)	

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
Wildlife Conservation Board (WCB), *continued*				
Habitat Enhancement and Restoration Program	WL, RW	Program provides funding for a wide variety of restoration projects, including those that restore habitat.	Habitat Conservation Fund, bonds	
Inland Wetlands Conservation Program	WL, AC	Program provides grants for acquisition of land or water for wetlands or wildlife-friendly agriculture, acquisition of conservation easements, restoration of public or private lands and enhancement of degraded habitats.	Habitat Conservation Fund, Inland Wetland Conservation Fund	Jurisdiction for the program includes most of the watershed of the Central Valley.
California Riparian Habitat Conservation Program	RR	Program develops coordinated conservation efforts aimed at protecting and restoring riparian ecosystems.	bond; Proposition 1E	
Stream Flow Enhancement Program	RR	Program provides funding for projects that enhance stream flows, including those that protect and restore functional ecological flows for streams identified as priority for fish and wildlife.	Proposition 1 ($200 million)	
Department of Water Resources (DWR)				
Flood Corridor Program	RR	Program provides grant funding to proponents of nonstructural flood management projects throughout the state that will include wildlife habitat enhancement and/or agricultural land preservation.	Propositions 13, 84, 1E	
Urban Streams Restoration Program/ Riverine Stewardship Program	RR	Program provides grants for projects that restore streams, creeks and rivers to enhance the environment for fish, wildlife and people.	Propositions 13, 84, 68	These two programs, both administered by DWR, are run in coordination with one another.
California Natural Resources Agency (CNRA)				
Urban Greening Program	UF	Program funds projects that reduce GHG emissions by sequestering carbon, decreasing energy consumption and reducing VMT, particularly projects that expand urban tree canopy.	GGRF	
Environmental Enhancement and Mitigation Program	UF, AC, WL	Program provides competitive funding for projects to plant trees or other vegetation, or for the acquisition, restoration and enhancement of resource lands, to help mitigate impacts to lands by transportation facilities.	transportation fees	Examples of eligible activities include enhancing and expanding urban forest and green space, restoring and expanding flood plains and preserving and protecting agricultural lands, open space, wetlands and other natural areas through land acquisitions.

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
California Department of Conservation (DOC)				
Sustainable Agricultural Lands Conservation (SALC) Program	AC	Program funds permanent agricultural easements on agricultural lands that are at risk of development and funds local governments to improve farmland conservation policy and program development; administered by DOC in partnership with the Strategic Growth Council.	GGRF	The program, a component of the Strategic Growth Council's Affordable Housing and Sustainable Communities (AHSC) Program, complements urban-area investments to develop a more resilient agricultural sector.
Transformative Climate Communities (TCC) Program	AC	Program funds community-led development and infrastructure climate projects that achieve major environmental, health and economic benefits in California's most disadvantaged communities. Administered by DOC in partnership with the Strategic Growth Council.	GGRF	
Agricultural Land Mitigation Program (ALMP)	AC	Program provides grant funding for the purchase of agricultural conservation easements on farmland within Fresno, Madera, Merced, Kern, Kings or Tulare Counties.	California High-Speed Rail Authority	
California Farmland Conservancy Program (CFCP)	AC	Program provides grants that support local efforts to establish agricultural conservation easements and planning projects for the purpose of preserving important agricultural land resources.	General Fund, EFLP, the Soil Conservation Fund and proceeds from Propositions 12, 40 and 84	
Williamson Act (also known as the California Land Conservation Act of 1965)	AC	The Williamson Act enables local governments to enter into contracts with private landowners for the purpose of restricting land use to agricultural or open-space uses. In return, landowners receive lower property tax assessments based on agricultural and open-space use.	none (State funding ended in 2009)	Between 1972 and 2009, the Open Space Subvention Act of 1971 provided local governments with an annual State subvention payment to make up for lost property tax revenues. Subvention payments ceased in 2009, effectively ending State support of the program; the program is now entirely implemented on a local basis.
State Coastal Conservancy				
Climate Ready Program	AC, UF, WL, RW	The program supports multibenefit projects that use nature-based solutions to mitigate climate change while providing additional benefits for people, wildlife and the economy. The program promotes collaboration, addresses the needs of low-income and other underserved coastal populations and promotes demonstration projects.	Proposition 68 and some GGRF funds (for grants awarded in 2018 and 2019)	The State Coastal Conservancy has awarded $10.7 million for 57 Climate Ready grants to date. These include sea level rise adaptation planning, the implementation of natural infrastructure for living shorelines, rangeland and agricultural adaptation, carbon sequestration and urban greening, among others. This program was codified by SB 576 (Umberg, Chapter 374, Statutes of 2019).

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
State Coastal Conservancy, *continued*				
Grants	AC, UF, WL	Grants fund a wide variety of projects along the California Coast, San Francisco Bay and coastal watersheds. Projects protect and restore natural lands and wildlife habitat, preserve working lands and increase resilience to climate impacts while ensuring continued public access to the coast.		
California Department of Fish and Wildlife (CDFW)				
Timberland Conservation Program	RW, CF, PR	Program helps to conserve public trust resources on private and state timberlands by reviewing timber harvesting plans, preparing permits, guiding forest habitat restoration and engaging in forestry-sector policy and regulatory reform, among other actions.	Timber Regulation and Forest Restoration Fund	
Cannabis Tax Fund	RW	Program provides funding for the cleanup, remediation and restoration of watersheds from cannabis grows.	excise tax	
California Department of Forestry and Fire Protection (CAL FIRE)				
Forest Health Grant Program	RW, PR	Program awards grants allocated from GGRF (as part of California Climate Investments) for projects that restore forest health and conserve working forests, protect watersheds, promote long-term storage of carbon in trees and soils and further goals of AB 32. Activities may include forest fuels reduction, prescribed fire, pest management, reforestation, biomass utilization, conservation easements and land acquisition (see California Forest Legacy Program and Federal Forest Legacy Program, below) and research.	GGRF	
California Forest Legacy Program	RW	Program provides Working Forest Conservation Easements (WFCEs), along with other relevant land-purchase costs, for productive forest lands to encourage their long-term conservation. Eligible properties include those with working forest and rangelands, with priority given to lands that can be effectively managed and protected and that have important scenic, recreational, timber and riparian value; value for fish and wildlife and threatened and endangered species; and other cultural and environmental values.	GGRF	CAL FIRE administers both the California Forest Legacy Program and the Federal Forest Legacy Program, which are separate but complementary. The two programs operate in a similar way but have different funding sources and different requirements on the entity that holds the easement. Application timeline and materials also vary for the two programs.

continued

TABLE A-1. Federal and State Policies Related to Nature-based Climate Solutions in California, *continued*

Policy action, resource or opportunity	Related nature-based solutions	Description	Funding source (if applicable)	Notes
California Department of Forestry and Fire Protection (CAL FIRE)				
Federal Forest Legacy Program	RW	Program provides Working Forest Conservation Easements (WFCEs), (along with other relevant land-purchase costs) for productive forest lands to encourage their long-term conservation. Eligible properties include those with working forest and rangelands, with priority given to lands that can be effectively managed and protected and that have important scenic, recreational, timber and riparian value; value for fish and wildlife and threatened and endangered species; and other cultural and environmental values.	Federal Land and Water Conservation Fund	CAL FIRE administers both the California Forest Legacy Program and the Federal Forest Legacy Program, which are separate but complementary. The two programs operate in a similar way but have different funding sources and different requirements on the entity that holds the easement. Application timeline and materials also vary for the two programs.
Urban and Community Forestry Program	UF	Program provides grants to expand and improve the management of trees and related vegetation in California communities and to advance other urban forestry efforts.	GGRF	
Forest Health and Fire Prevention	RW	Program provides grants to implement projects that proactively restore forest health and conserve working forests, protect upper watersheds, promote the long-term storage of carbon in forest trees and soils, minimize the loss of forest carbon from wildfires and engage in other activities that further the goals of AB 32.	GGRF, General Fund	Eligible projects include fuel reduction, prescribed fire, pest management, reforestation, biomass utilization, conservation easements and research. Projects must be durable and focus on large, landscape-scale forestlands and maintain net GHG reductions.
California Forest Improvement Program (CFIP)	RW, CF	Program provides cost-sharing grants to landowners for management planning, site preparation, tree purchase and planting, timber stand improvement, habitat improvement and land conservation.	Timber Regulation and Forest Restoration Fund	
California Vegetation Management Program (VMP)	RW	Program provides assistance to landowners in State Responsibility Areas (SRAs) for wildfire risk reduction activities through the use of prescribed fire and thinning.	GGRF	
California Vegetation Treatment Program (CalVTP)	RW	Program directs the implementation of vegetation treatments on public and private land to reduce the risk of loss of lives and property, reduce fire suppression costs and protect natural resources from wildfire.	General Fund and GGRF (via SB 901)	The CalVTP Program streamlines fire fuel reduction project approval processes, expediting projects under CAL FIRE's Prescribed Fire, Healthy Forest and Fire Prevention programs.

*AC = avoided conversion; AF = agroforestry; CA = compost application; CC = cover cropping; CF = changes in forest management; NM = nitrogen management; PR = post-wildfire reforestation; RC = rice cultivation; RR = riparian restoration; RW = reduced wildfire severity; UF = urban reforestation; WL = wetland restoration; WR = woodland restoration

TABLE A2. Scenario analysis and decision support tools for nature-based solutions

Tool	Relevant nature-based solutions*	Description	Developer(s)	Link
Bay Area Greenprint	numerous	Tool provides a regional source of accessible conservation data and a framework for planners, agencies and others to inform land-use and infrastructure planning with natural and working lands information.	The Nature Conservancy, American Farmland Trust, Bay Area Open Space Council, Greenbelt Alliance and GreenInfo Network	https://maps.conservation.ca.gov/terracount/
CropManage	NM	This free, online, database-driven tool assists growers and farm managers in determining water and nitrogen fertilizer applications on a field-by-field basis.	University of California Agriculture and Natural Resources (UC ANR)	https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=8501
CALAND	numerous	Initiative estimates the effects of a number of land management activities on California's landscape carbon budget, based on field data from California. Outputs include annual estimates of carbon stocks and fluxes, GHG emissions, wood product storage and decay and potential bioenergy feedstock.	California Natural Resources Agency	https://data.cnra.ca.gov/dataset/caland-version-3
Closing the Tree Gap	UF	This beta tool explores the links among urban tree cover, summer temperature, urban heat island effects and income over three California cities (Los Angeles, Sacramento and Riverside).	The Nature Conservancy in California	https://shree1175.users.earthengine.app/view/tnc-ca-treeinequality131
Comet Planner	AC, NM, CC, AF, RR	This tool provides GHG estimation methods based on USDA entity-scale GHG inventory guidance, as well as scenario analysis for NRCS practice implementation.	USDA-NRCS, Colorado State University	http://comet-planner.com/
EcoAtlas	WL	This tool provides access to information for effective wetland management, including restoration information.	San Francisco Estuary Institute – Aquatic Science Center	https://www.ecoatlas.org/
i-Tree	UF	This tool provides urban and rural forestry analysis and benefits assessment tools that can be used to quantify forest structure and the environmental benefits that trees provide.	USDA Forest Service	https://www.itreetools.org/
TerraCount	numerous	This scenario analysis tool models GHG and natural resource implications of different development patterns and land management activities.	California Department of Conservation (DOC)	https://maps.conservation.ca.gov/terracount/
Urban Footprint	AC	This cloud-based urban intelligence software provides data and tools for planners to address climate change, housing affordability, mobility and more.	Urban Footprint	https://urbanfootprint.com/

*AC = avoided conversion; AF = agroforestry; CA = compost application; CC = cover cropping; CF = changes in forest management; NM = nitrogen management; PR = post-wildfire reforestation; RC = rice cultivation; RR = riparian restoration; RW = reduced wildfire severity; UF = urban reforestation; WL = wetland restoration; WR = woodland restoration.

Appendix B: Methods for Spatial Analysis

This report builds on a growing body of scientific work that estimates the GHG emission reduction potential of nature-based climate solutions. Collectively, this report considers and provides policy recommendations for the estimated reduction benefits of 13 solutions relevant to California's natural and working lands (table B-1), based on scientific findings from three studies:

- Cameron et al. (2017) used a scenario-based analysis to estimate the cumulative GHG reduction potential from a set of land conservation, management and restoration activities (defined across five nature-based climate solutions in California), finding that an ambitious implementation scenario in California could contribute as much as 147 MMT CO^2e—or approximately 17% of the cumulative reductions needed by the State for its 2030 goal. These reductions come from changes in forest management, followed by post-wildfire reforestation, avoided conversion, compost application to grasslands and wetland restoration.
- Fargione et al. (2018) estimated the maximum annual mitigation potential of 21 nature-based climate solutions across the United States. This analysis found that nature-based climate solutions have the potential to generate greenhouse gas mitigation equivalent to 21% of the United States' net annual emissions.
- Marvin et al. (2018) used a scenario-based analysis to spatially quantify the GHG reduction potential of eight nature-based climate solutions across California. This study found that these solutions could capture as much as 260 MMT CO^2e, or approximately 5 to 7% of emission reductions needed for the State to meet its 2045 carbon neutrality goal.

Eight of the 13 solutions presented in this report were mapped by Marvin et al. (2018).[35] An additional five solutions were mapped for this report. It is worth noting that "mapping" means something slightly different in Marvin et al. and in this report. The data in this report derived from Marvin et al. represent locations chosen by a model based on a specified implementation area. The five newly mapped solutions in this report represent the universe of all suitable locations for solution implementation.

TABLE B1. Summary of relationship between solutions discussed in this report and various studies

GHG reduction estimates for these solutions…	…are based on results of these studies
avoided conversion	Marvin et al. (2018)*
changes to forest management	Marvin et al. (2018)
compost application	Cameron et al. (2017)
post-wildfire reforestation	Marvin et al. (2018)
reduced wildfire severity	Marvin et al. (2018)†
woodland restoration	Marvin et al. (2018)
riparian restoration	Marvin et al. (2018)
agroforestry	Fargione et al. (2018)
cover cropping	Marvin et al. (2018)
nitrogen management	Fargione et al. (2018)
rice cultivation	Fargione et al. (2018)
urban reforestation	Fargione et al. (2018)
wetland restoration	Cameron et al. (2017)

*Marvin et al. considered two projected future climate scenarios, a "hot and dry" future and an "average" future. Results from Marvin et al. used in this report are based on the "average" future climate.

†The numbers used in this report reflect Marvin et al.'s reduced wildfire severity (30%) intervention.

The result is a statewide assessment for 13 nature-based climate solutions, showing how the implementation of nature-based climate solutions across California reduces GHG emissions while providing additional social, environmental and economic co-benefits. We applied the annual reduction estimates from Fargione et al. (2018) to estimate the total cumulative GHG reduction potential from agroforestry, urban reforestation, nitrogen management and rice cultivation, as well as the total cumulative GHG reduction estimates from Cameron et al. (2017) for wetland restoration and compost application. The analyses for newly mapped activities are briefly described below.

Methodology Details: Newly Mapped Nature-based Climate Solutions

Urban Reforestation

Urban tree cover per capita in California is the lowest among all 50 states, indicating that there is ample opportunity for tree planting (McPherson et al. 2017). Additionally, tree planting through urban reforestation activities has the potential to reduce nationwide GHG emissions by up to 23 MMT CO_2e per year (Fargione et al. 2018). Using these facts as starting points, we assessed the opportunity for urban reforestation across California, focusing our analysis on census-defined urban areas (pockets of wildland were excluded from analysis).

The initial analysis was conducted using land-use types that were classified according to the intensity of development present (low, medium and high), as well as developed open space (Jin 2016), across all of California. Total tree cover within the developed class was assessed using the FRAP 1-meter Urban Tree Cover product over 30-meter squares, and included canopy covers ranging from 1 to 900 square meters. Areas extending beyond census-block tracts, exurban areas and impervious surfaces (such as buildings or parking lots) were excluded. Additionally, a 30-meter mask was applied to remove all pixels that offered less than 90 square meters of area for tree planting. This 30-meter analysis resulted in an estimate of the potential for urban reforestation (in terms of suitable acres) across all urban areas of the state. However, these results were somewhat coarse, and potentially overestimate actual urban reforestation potential in California.

To produce a more realistic estimate of suitable acres, a more detailed analysis was conducted within three cities: Sacramento, Los Angeles and Riverside. This analysis was conducted at a census-block level, allowing urban reforestation potential to be probed as a function of tree cover inequity and summer temperature disparity—factors that, in turn, relate to income disparities and population density.

To estimate GHG reduction potential for urban reforestation, total suitable acres from both the initial statewide analysis and the census block-level analyses were multiplied by a factor of 7.34 tons CO_2e per hectare per year (converted to acres per year), derived from Nowak et al. (2013), who investigated the carbon sequestration associated with urban trees.

On a statewide scale, our analysis shows how empty land might be strategically transformed to increase tree cover and mitigate climate change. Our detailed, census block-level analyses provide additional unique opportunities to strategically benefit low-income and disadvantaged communities and to spatially assess optimal locations (at the census-block level) for urban reforestation.

The "Tree Gap Closing" beta-tool (linked in Appendix A), developed from our census block-level analysis, is a tool that uses the methods described above to strategically plan urban reforestation projects that can benefit low-income and disadvantaged communities. Closing the tree gap will help to sequester carbon, reduce summer temperatures and GHG emissions and provide multiple additional benefits for people and nature (McDonald et al. 2020; Wang and Akbari 2016; Ziter et al. 2019).

Compost Application to Grasslands and Rangelands

Compost application was mapped based on the potential to increase and maintain soil organic carbon through the application of compost on nonirrigated Mediterranean grasslands and rangelands. Total suitable acres were determined by limiting the analysis to lands with upland herbaceous vegetation (CAL FIRE 2015) and slopes of less than 20%, located within 3,000 feet of existing roadways within Mediterranean grasslands. The analysis excluded areas that were already protected as designated wilderness areas, state parks, national parks and certain other areas; were already classified as existing wetlands; were near water bodies; or that fell under serpentine soils. Tables B-2 and B-3 shows all the input variables that were included in this analysis.

Improved Nitrogen Fertilizer Management

The analysis by Fargione et al. showed that more efficient use of fertilizer can reduce nitrous oxide (N_2O) emissions. These emissions are poised to increase in the

TABLE B-2. Input datasets and criteria for mapping potential acres for five nature-based solutions in California

Nature-based solution mapped	Data layer	Data source(s)
compost application	slope	National Elevation Dataset
	protected lands	California Protected Access Database
	vegetation	CalFire FVEG
	serpentine soils	United States Geological Survey, Data Series 414
	ecoregions	The Nature Conservancy (Dominick Ecoregions)
	existing wetlands	National Wetlands Inventory, Sonoma Veg Map, Vernal Pools (TNC), Bay Area Aquatic Resource Inventory (SFEI)
	areas near water	National Hydrography Dataset (flow lines, water bodies)
	roads	Open Street Map
wetland restoration	existing wetlands	National Wetlands Inventory, Sonoma Veg Map, Vernal Pools (TNC), Bay Area Aquatic Resource Inventory (SFEI)
	historic wetlands	Southern California T-Sheets (SFEI), Sacramento Delta Historic Ecology (SFEI), Historic San Francisco Baylands (SFEI), Historic Soils (SFEI)
	vegetation	CalFire FVEG
	rice	Cropscape (2018)
	hydric soils	NRCS SSURGO
	coastal wetland	TNC Coastal Assessment
urban reforestation	statewide urban canopy cover (1 meter)	CalFire FRAP
	national land cover dataset (30 meters)	U.S. Geological Survey
	national land cover dataset impervious product (30 meters)	U.S. Geological Survey
	census-defined urban areas	U.S. Census Bureau
nitrogen management	nitrogen fertilizer sold	U.S. Geological Survey
rice cultivation	rice fields	Cropscape (2018)

United States, given a 4.6% expected increase in the use of fertilizer by 2025. Fargione at al. (2018) compared four improved management practices for N_2O application and concluded that a 22% reduction in nitrogen use will reduce emissions by 33% without adversely affecting crop yield.

Due to lack of available data on N_2O use on croplands, we used statewide total farmland as a proxy for N_2O application.[36] Assuming that N_2O application is suitable for and equally applied across all crop types, we calculated the acreage of farmland in each county, using that acreage to estimate the acreage of N_2O fertilizer opportunity.

The result is an estimate of suitable locations for N_2O, which is less accurate than the suitable acres modeled for the other nature-based climate solutions. Obtaining a more accurate assessment of suitable locations would require additional information to describe how N_2O usage varies with crop type. Because N_2O opportunity was determined through this proxy rather than modeled suitable acres, this solution was not mapped alongside the other solutions in figure 4A, which displays modeled suitable acres.

Best Management Practice Through Rice Cultivation

California's rice is grown on soils that are unsuitable for other crops because of poor drainage. This type of land is ideal for rice production and produces the world's highest rice crop yields (California Rice 2012); in fact, California rice growers produce 20% more than the U.S. average.

GHGs are generated throughout the various stages of rice production, but improved practices in flooded rice

TABLE B-3. Input datasets for co-benefit layers

Co-benefit	Data layer	Source
disadvantaged communities	top quartile among most disadvantaged communities as defined in SB535	OEHHA (2018)
low-income communities	low-income communities as defined under AB 1550	OEHHA (2018)
high-quality agricultural land	Farmland Mapping and Monitoring Program (FMMP)	CDC (2016, 2018)
connectivity	TNC Omnidirectional Circuitscape Model for Climate Change Connectivity	Cameron and Schloss (2018)
flood risk reduction	100-year flood plain	Wing (2017)
groundwater recharge	California Basin Characterization Model, downscaled climate and hydrology—30-year summaries—recharge	Flint and Flint (2014)
groundwater recharge on agricultural land	Soil Agricultural Groundwater Banking Index (SAGBI)	O'Geen et al. (2015)
habitat resilience	Vegetation Exposure, Model MIROC-ESM, RCP8.5 (1981-2010 and 2070-2099)	Thorne et al. (2017)
	Vegetation Exposure, Model CNRM-CM5, RCP8.5 (1981-2010 and 2070-2099)	Thorne et al. (2017)
open space	California Protected Areas Database (CPAD)	GreenInfo Network (2020)
high-quality species habitat	Plant Species Richness Index	Kling et al. (2018)
	California Mammal Richness Index	Stewart et al. (2016)
	California Amphibian and Reptile Richness	Wright et al. (2013)
	California Bird Species Richness Index	Point Blue Conservation Science (2010)

cultivation can lead to avoided emissions of methane (CH_4) and nitrous oxide. These improved practices include midseason drainage of flooded fields, alternate wetting and drying and residue removal.

To analyze the GHG reductions possible from implementing best management practices for flooded rice cultivation, we used 2018 Cropscape data showing areas of rice cultivation and assumed that all these areas would benefit from improved practices. We used Fargione et al.'s reduction rate to estimate the annual GHG reduction potential. This analysis did not take into account any impacts of climate change or land-use change that might result in changes to crop cultivation.

Wetland Restoration

Total suitable acres for wetland restoration were determined as a composite of total freshwater and coastal wetland. In the United States, 27% of tidal wetlands (which include salt marshes and mangroves) have limited tidal connection with the sea. This causes their salinity to decline to the point that methane emissions increase (Kroeger et al. 2017). We included potential coastal wetlands in our analysis because we wanted to account for all areas that may become potential sources of future GHG emissions due to sea level rise.

Areas suitable for freshwater wetlands were mapped within upland herbaceous vegetation and historic wetland if they had hydric soils (NRCS SSURGO) and were nonforest (CAL FIRE 2015) or non-rice cultivated areas (Cropscape 2018). The suitability analysis included available nonperennial croplands (Cropscape 2018) if they met the above criteria—and excluded existing wetland. Total potential coastal wetland habitat, taken from the TNC Coastal Assessment (Heady et al. 2018), includes the extent of coastal habitats that need to be conserved for their future habitat value due to sea level rise. The analysis identified—as opportunities for conserving "potential future habitat"—areas with minimal development (e.g., agriculture and developed open space) that are projected to be inundated by sea level rise or are adjacent to vulnerable habitats.

Statewide, there are close to 200 square kilometers of potential coastal wetland habitat that could help mitigate the potential loss of vulnerable habitats to sea level rise. The total area of coastal and freshwater wetland was aggregated to calculate total potential area for wetland

restoration area statewide. Due to variable GHG reduction rates between coastal and inland wetland, we used Cameron et al. (2017) to report the cumulative GHG emission reductions from all four wetland restoration solutions in the paper.

Co-benefit Analysis

To aid decision-makers in considering where nature-based climate solutions might best be implemented, we provide in this report a rough metric of ecological benefits across the state, including (among others) groundwater recharge potential and high-quality species habitat. Table B-2 provides a list of all the co-benefits that were evaluated in tandem with the 13 solutions. California Department of Fish and Wildlife (CDFW) ACE-II hexagons (CDFW 2018) were used to summarize total acres for each solution and each co-benefit within 1,600-acre hexagons. The analysis by hexagon allowed us to probe areas of overlap between each nature-based solution and corresponding co-benefits, resulting in a statewide heat map of co-benefits (see fig. 4). In this heat map, predominant colors represent co-benefits with the largest spatial extent within each 1,600-acre hexagon.

Application to Low-income and Disadvantaged Communities

Twenty-five million acres of land suitable for nature-based climate solutions falls within disadvantaged and low-income communities. This accounts for more than 60% of all suitable land (for nature-based climate solutions) in California. reduced wildfire severity alone offers the opportunity to reduce GHGs in 9.5 million acres of low-income communities, many of which are located in the North Coast and Sierra Nevada and Southern Cascades regions.

Other nature-based solutions that offer substantial potential in disadvantaged and low-income communities include changes in forest management (2 million acres), compost application (2.1 million acres), avoided conversion (1.3 million acres), post-wildfire reforestation (1.3 million acres), reduced wildfire severity (9 million acres) and wetland restoration (1.3 million acres). These six solutions add up to more than 14 million acres of opportunity for low-income communities and 2 million acres for disadvantaged communities.

Figure 8 shows that suitable acres for nature-based climate solutions in California overlap significantly with low-income and disadvantaged communities. In addition to reduced wildfire severity, wetland restoration, agroforestry, post-wildfire reforestation, changes in forest management and cover cropping directly account for more than 60% of the area for nature-based solutions that will directly benefit low-income and disadvantaged communities.

References

(CDC) California Department of Conservation. 2016. Farmland mapping and monitoring program. https://www.conservation.ca.gov/dlrp/fmmp/

(CDC) California Department of Conservation. 2018. Farmland mapping and monitoring program. https://www.conservation.ca.gov/dlrp/fmmp/

(CAL FIRE) California Department of Forestry and Fire Protection. 2015. FVEG Data: Vegetation (fveg)—CAL FIRE FRAP [ds1327]. https://map.dfg.ca.gov/metadata/ds1327.html

California Rice. 2012. Environmental sustainability report. Prepared for the California Rice Commission. https://calrice.org/pdf/Sustainability+Report.pdf

Cameron, D. R., D. C. Marvin, J. M. Remucal, and M. C. Passero. 2017. Ecosystem management and land conservation can substantially contribute to California's climate mitigation goals. Proceedings of the National Academy of Sciences 114(48):12833-12838. https://doi.org/10.1073/pnas.1707811114

(CARB) California Air Resources Board. 2018. An inventory of ecosystem carbon in California's natural and working lands. https://ww3.arb.ca.gov/cc/inventory/pubs/nwl_inventory.pdf

CropScape. 2018. USDA National Agricultural Statistics Service Cropland Data Layer. https://nassgeodata.gmu.edu/CropScape/

Fargione, J. E., S. Bassett, T. Boucher, S. D. Bridgham, R. T. Conant, S. C. Cook-Patton, P. W. Ellis, A. Falcucci, J. W. Fourqurean, T. Gopalakrishna, H. Gu, B. Henderson, M. D. Hurteau, K. D. Kroeger, T. Kroeger, T. J. Lark, S. M. Leavitt, G. Lomax, R. I. McDonald, J. P. Megonigal, D. A. Miteva, C. J. Richardson, J. Sanderman, D. Shoch, S. A. Spawn, J. W. Veldman, C. A. Williams, P. B. Woodbury, C. Zganjar, M. Baranski, P. Elias, R. A. Houghton, E. Landis, E. McGlynn, W. H. Schlesinger, J. V. Siikamaki, A. E. Sutton-Grier. and B. W. Griscom. 2018. Natural climate solutions for the United States. Science Advances 4(11):1-14. https://doi.org/10.1126/sciadv.aat1869

Flint, L. E., and A. L. Flint. 2014. California basin characterization model: A dataset of historical and future hydrologic response to climate change, version 1.1. U.S. Geological Survey Data Release. https://doi.org/10.5066/F76T0JPB

Gonzalez, P., J. J. Battles, B. M. Collins, T. Robards, and D. S. Saah. 2015. Aboveground live carbon stock changes of California wildland ecosystems, 2001-2010. Forest Ecology and Management 348:68-77. https://doi.org/10.1016/j.foreco.2015.03.040

GreenInfo Network. 2020. California protected areas database. https://www.calands.org

Heady, W. N., B. S. Cohen, M. G. Gleason, J. N. Morris, S. G. Newkirk, K. R. Klausmeyer, H. Walecka, E. Gagneron, and M. Small. 2018. Conserving California's coastal habitats: a legacy and a future with sea level rise. San Francisco: The Nature Conservancy; Oakland: California State Coastal Conservancy. https://www.scienceforconservation.org/products/coastal-assessment

Jin, S., C. G. Homer, L. Yang, P. Danielson, J. Dewitz, C. Li, Z. Zhu, G. Xian, and D. Howard. 2019. Overall methodology design for the United States National Land Cover Database 2016 products. Remote Sensing 11(24). https://doi.org/10.3390/rs11242971

Kling, M. M., B. D. Mishler, A. H. Thornhill, B. G. Baldwin, and D. D. Ackerly. 2018. Facets of phylodiversity: evolutionary diversification, divergence, and survival as conservation targets. Philosophical Transactions of the Royal Society B 374(1763): 20170397. https://doi.org/10.1098/rstb.2017.0397

Kroeger, K. D., S. Crooks, S. Moseman-Valtierra, and J. Tang. 2017. Restoring tides to reduce methane emissions in impounded wetlands: a new and potent Blue Carbon climate change intervention. Scientific Reports 7:11914. https://doi.org/10.1038/s41598-017-12138-4

Marvin, D.C., D. R. Cameron, E., Nelson, A. Plantinga, J. Breck, G. Sencan, and M. Passero. 2018. Toward a carbon neutral California: economic and climate benefits of land use interventions. San Francisco: Next 10. https://www.next10.org/publications/land-carbon

McDonald, R. I., T. Kroeger, P. Zhang, and P. Hamel. 2020. The value of US urban tree cover for reducing heat-related health impacts and electricity consumption. Ecosystems 23:137-150. https://doi.org/10.1007/s10021-019-00395-5

McPherson, E. G., Q. Xiao, N. S. van Doorn, J. de Goede, J. Bjorkman, A. Hollander, R. M. Boynton, J. F. Quinn, and J. H. Thorne. 2017. The structure, function, and value of urban forests in California communities. Urban Forestry and Urban Greening 28:43-53. https://doi.org/10.1016/j.ufug.2017.09.013

Nowak, D. J., E. J. Greenfield, R. E. Hoehn, and E. Lapoint. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution 178:229-236. https://doi.org/10.1016/j.envpol.2013.03.019

(OEHHA) California Office of Environmental Health Hazard Assessment. 2018. CalEnviroScreen 3.0. https://oehha.ca.gov/calenviroscreen/maps-data

O'Geen A., M. Saal, H. Dahlke, D. Doll, R. Elkins, A. Fulton, G. Fogg, T. Harter, J. Hopmans, C. Ingels, F. Niederholzer, S. Solis, P. Verdegaal, and M. Walkinshaw. 2015. Soil suitability index identifies potential areas for groundwater banking on agricultural lands. California Agriculture 69(2):75-84. https://doi.org/10.3733/ca.v069n02p75

Point Blue Conservation Science. 2010. Environmental Change Network: modeling bird distribution responses to climate change. http://climate.calcommons.org/dataset/14

Stewart J. A. E., J. H. Thorne, M. Gogol-Prokurat, and S. D. Osborn. 2016. A climate change vulnerability assessment for twenty California mammal taxa. UC Davis Information Center for the Environment. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=135825&inline

Thorne J. H., H. Choe, R. M. Boynton, J. Bjorkman, W. Albright, K. Nydick, A. L. Flint, L. E. Flint, and M. W. Schwartz. 2017. The impact of climate change uncertainty on California's vegetation and adaptation management. Ecosphere 8(12):e02021. https://doi.org/10.1002/ecs2.2021

Wang, Y., and H. Akbari. 2016. The effects of street tree planting on Urban Heat Island mitigation in Montreal. Sustainable Cities and Society 27:122–128. https://doi.org/10.1016/j.scs.2016.04.013

Wing, O. E. J., P. D. Bates, C. C. Sampson, A. M. Smith, K. A. Johnson, and T. A. Erickson. 2017. Validation of a 30 m resolution flood hazard model of the conterminous United States. Water Resources Research 53(9):7968–7986. https://doi.org/10.1002/2017WR020917

Wright, A. N., R. J. Hijmans, M. W. Schwartz, and H. B. Shaffer. 2013. California amphibian and reptile species of future concern: conservation and climate change. UC Davis final report to the California Department of Fish and Wildlife Nongame Wildlife Program, Task 12, Contract No. P0685904. climate.calcommons.org/bib/california-amphibian-and-reptile-species-future-concern-conservation-and-climate-change

Ziter, C. D., E. J. Pedersen, C. J. Kucharik, and M. G. Turner. 2019. Scale-dependent interactions between tree-canopy cover and impervious surfaces reduce daytime urban heat during summer. Proceedings of the National Academy of Sciences 116(15):7575-7580. https://doi.org/10.1073/pnas.1817561116

Appendix C: Methods for Economic Analysis

This report provides, where possible, estimates of the costs associated with each nature-based climate solution analyzed. These estimates include 1) the costs, in terms of economic damages, of emitting 1 ton of CO_2e per year (often referred to as the social cost of carbon, or SCC), evaluated over a 30-year time window (to 2050) and 2) the costs needed to reduce 1 ton of carbon dioxide equivalent (CO_2e). Methods used to assess these costs are described briefly below.

Social Cost of Carbon

The SCC is an estimate of the economic damages that would result from emitting 1 additional ton of GHGs into the atmosphere—and includes (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk and the value of ecosystem services due to negative climate impacts.

The federal Interagency Working Group on Social Cost of Carbon (IWG), which operated from 2010 to 2017, developed estimates for the SCC, shown in table C-1, in 2007 dollars, for different discount rates.[37] As the table shows, the SCC increases over time; this is because future GHG emissions are anticipated to cause increasingly severe damages as ecosystems and economic systems become more stressed due to climate change. The discount rates that accompany SCC values in table C-1 capture the trade-offs between action now or later, collectively representing how future damages are valued relative to damages in previous periods.

To determine these savings for the 13 nature-based solutions analyzed in this report, the IWG SCC was first translated into 2019 dollars using the U.S. Bureau of Labor Statistics' Consumer Price Index (CPI).[38] The values for years 2020 onward were then multiplied by the corresponding cumulative reductions to estimate the savings from avoided damages. These results are shown in table C-2, rounded to the nearest million U.S. dollars. The savings from SCC shown throughout the report reflect the 3% discount rate. The SCC was not calculated for reduced wildfire severity or woodland restoration because these solutions do not achieve net emission reductions on the 2050 time horizon.

Cost-effectiveness

Cost-effectiveness for an activity can be expressed as the ratio of cost to measurable effect. In the context of climate mitigation, measurable effects are described in terms of GHG reduction potential. Cost-effectiveness can thus be described as a cost per metric ton of CO_2e removed.

TABLE C-2. Economic benefit from cumulative reductions (2019 U.S. dollars, millions)

Nature-based climate solution	Social cost of carbon (2019 U.S. dollars, millions)
avoided conversion	6,520
changes to forest management	8,389
compost amendment	295
post-wildfire reforestation	932
riparian restoration	228
agroforestry	1,243
cover cropping	1,538
nitrogen management	3,713
rice cultivation	994
urban reforestation	2,812
wetland restoration	1,049

In this report, estimates for cost per metric ton are provided for five solutions for which Marvin et al. (2018) provided total economic cost data: avoided conversion, changes to forest management, cover cropping, post-wildfire reforestation and riparian restoration. As with the SCC calculations above, no cost per ton was determined for reduced wildfire severity or woodland restoration because the measurable effect (GHG reduction) was not positive on a 30-year timescale.

The total economic cost for each nature-based solution, as determined by Marvin et al., is the sum of direct implementation costs and opportunity costs from land value. Total economic costs (using Marvin et al.'s "average" climate future) were inflated to 2019 U.S. dollars with the CPI and divided by cumulative GHG emissions to produce a cost per metric ton.

Although not included in this report, rough cost estimates for other nature-based climate solutions can be gleaned by considering funds spent through the GGRF/CCI, which are detailed in the State's annual report on California Climate Investments (California Climate Investments 2020).

TABLE C-1. Social cost of CO_2, 2020-2050. Reported costs in this report use a 3% discount rate, highlighted in green below.

Year	Social cost of carbon, 2020-2050 (2007 U.S. dollars)			Social cost of carbon, 2020-2050 (2019 U.S. dollars)			Discounted social cost of carbon (2019 U.S. dollars)		
	5% average	3% average	2.5% average	5% average	3% average	2.5% average	5% average	3% average	2.5% average
2020	12	42	62	14.80	51.79	76.45	14.80	51.79	76.45
2021	12	42	63	14.80	51.79	77.68	14.09	50.28	75.78
2022	13	43	64	16.03	53.02	78.91	14.54	49.98	75.11
2023	13	44	65	16.03	54.25	80.15	13.85	49.65	74.42
2024	13	45	66	16.03	55.49	81.38	13.19	49.30	73.72
2025	14	46	68	17.26	56.72	83.84	13.53	48.93	74.11
2026	14	47	69	17.26	57.95	85.08	12.88	48.53	73.36
2027	15	48	70	18.50	59.18	86.31	13.14	48.12	72.61
2028	15	49	71	18.50	60.42	87.54	12.52	47.69	71.85
2029	15	49	72	18.50	60.42	88.78	11.92	46.30	71.09
2030	16	50	73	19.73	61.65	90.01	12.11	45.87	70.31
2031	16	51	74	19.73	62.88	91.24	11.53	45.43	69.54
2032	17	52	75	20.96	64.12	92.48	11.67	44.97	68.76
2033	17	53	76	20.96	65.35	93.71	11.12	44.50	67.98
2034	18	54	77	22.19	66.58	94.94	11.21	44.02	67.19
2035	18	55	78	22.19	67.82	96.17	10.68	43.53	66.40
2036	19	56	79	23.43	69.05	97.41	10.73	43.03	65.62
2037	19	57	81	23.43	70.28	99.87	10.22	42.52	65.64
2038	20	58	82	24.66	71.51	101.11	10.25	42.01	64.83
2039	20	59	83	24.66	72.75	102.34	9.76	41.49	64.02
2040	21	60	84	25.89	73.98	103.57	9.76	40.96	63.21
2041	21	61	85	25.89	75.21	104.81	9.29	40.43	62.40
2042	22	61	86	27.13	75.21	106.04	9.27	39.25	61.59
2043	22	62	87	27.13	76.45	107.27	8.83	38.73	60.79
2044	23	63	88	28.36	77.68	108.50	8.79	38.21	59.99
2045	23	64	89	28.36	78.91	109.74	8.37	37.69	59.19
2046	24	65	90	29.59	80.15	110.97	8.32	37.16	58.40
2047	24	66	92	29.59	81.38	113.44	7.93	36.64	58.24
2048	25	67	93	30.83	82.61	114.67	7.86	36.11	57.44
2049	25	68	94	30.83	83.84	115.90	7.49	35.58	56.64
2050	26	69	95	32.06	85.08	117.14	7.42	35.05	55.84

References

California Climate Investments. 2020. Annual report to the Legislature on California Climate Investments using cap-and-trade auction proceeds. https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/2020_cci_annual_report.pdf

Marvin, D.C., D. R. Cameron, E., Nelson, A. Plantinga, J. Breck, G. Sencan, and M. Passero. 2018. Toward a carbon neutral California: economic and climate benefits of land use interventions. San Francisco: Next 10. https://www.next10.org/publications/land-carbon

Appendix D: Glossary of Terms

Biomass The mass of living or dead vegetation.

Carbon cycle The continuous process by which carbon is transferred between living organisms and the environment.

Carbon dioxide equivalent A measure used to compare the emissions from various greenhouse gases based upon their potential to cause warming in the atmosphere.

Carbon sequestration The process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form.

Carbon stocks The amount of carbon contained in living and dead biomass, including trees, leaves, roots, soil and harvested wood.

Co-benefit A complementary benefit for people and nature that results from the implementation of activities to reduce GHG emissions.

Disadvantaged communities As defined by SB 535 (https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120SB535), areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, pollution exposure or environmental degradation; areas with concentrations of people with low incomes, high unemployment levels, low levels of home ownership or low levels of educational attainment, as well as people facing high rent burdens; and areas with high concentrations of people belonging to sensitive populations.

Ecosystem services The many benefits that ecosystems provide to people, such as clean air and water, food, timber and recreation.

Fallowing A farming technique in which agricultural land is left without sowing for a period of time before being cultivated again.

Greenhouse gases Gaseous compounds that trap heat in the atmosphere by absorbing infrared radiation, including (among other compounds) carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20).

Greenprint A plan or tool that reveals the ecological, social and economic attributes of natural lands, water resources, working landscapes, natural infrastructure, recreational lands and other open spaces as a way to represent and quantify the benefits provided by these lands to natural and human communities. These benefits may include the conservation of ecosystem values and functions, hazard risk reduction, water and soil conservation, biodiversity, climate change mitigation and resilience, public health and agriculture economic value.

Harvest rotation The time between planting and harvesting of forest trees.

Low-income communities As defined by AB 1550 (https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1550), census tracts with median household incomes at or below 80% of the statewide median income or with median household incomes at or below the threshold designated as low-income by the California Department of Housing and Community Development's list of state income limits.

Natural and working lands As defined in California's Public Resources Code (https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PRC&division=9.&title=&part=&chapter=1.&article=1), "working lands" means lands used for farming, grazing, or the production of forest products and "natural lands" means lands consisting of forests, grasslands, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas, watersheds, wildlands or wildlife habitat, or lands used for recreational purposes (such as parks, urban and community forests, trails, greenbelts and similar open-space land).

Nature-based climate mitigation Land management, restoration and conservation strategies that sequester carbon dioxide and/or reduce greenhouse gas emissions.

Prescribed burning A planned (or controlled) burn that is used as a tool to achieve specific land management goals.

Refugia Habitats providing environmental conditions not available in the surrounding landscape, to which biodiverse populations can retreat, and where they can possibly expand, over long periods of time.

Social cost of carbon A financial estimate of the economic damages that would result from emitting 1 additional ton of greenhouse gases into the atmosphere.

USDA-NRCS U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), an agency of the USDA that provides technical assistance to farmers and other private landowners and managers.

Endnotes

1 California's natural and working lands also include arid and desert spaces that support wildlife and sequester carbon. However, desert lands go beyond the scope of analysis presented in this report.

2 This is also known as "carbon sequestration."

3 These benefits are often referred to as "ecosystem services."

4 These strategies are also often referred to as "natural climate solutions."

5 Disadvantaged and low-income communities have been defined according to Senate Bill 535 (De León, Chapter 830, Statutes of 2012)—which uses a pollution-based metric—and Assembly Bill 1550 (Gomez, Chapter 369, Statutes of 2016)—which uses an income-based metric.

6 A number of other approaches have also been used to probe the emission reduction potential of California's natural and working lands. These include, among others, Baker et al. 2019, CARB 2019a, Ghabbour et al. 2017 and Swan et al. 2015.

7 Total economic costs for eight nature-based climate solutions were assessed by Marvin et al. (2018). In this report, GHG reduction potential for seven nature-based solutions (avoided conversion, reduced wildfire severity, post-wildfire reforestation, changes in forest management, riparian restoration, woodland restoration and cover cropping) is reported from the work by Marvin et al. Total economic cost data were thus available for these seven solutions. In this report, we only present cost per metric ton for solutions that provide positive GHG reduction benefits by the year 2050, thereby excluding reduced wildfire severity and woodland restoration.

8 Table A-1, in Appendix A, outlines federal and state policies. Though not comprehensive, it illustrates the breadth of available policy opportunities.

9 As a nature-based climate solution, "avoided conversion" refers to reducing rates of land conversion to urban or other uses.

10 CalEnviroScreen is a mapping tool that helps to identify California communities that are impacted by pollution (OEHHA 2020).

11 A number of tools and studies can be used to aid in such measures. For example, TNC is developing a science-based tool to prioritize areas for Urban Reforestation.

12 Because reduced wildfire severity doesn't result in net GHG reductions until beyond 2050, we do not provide estimates of cost-effectiveness or social cost of carbon for this activity.

13 Because woodland restoration doesn't result in net GHG reductions until beyond 2050, we do not provide estimates for cost-effectiveness or social cost of carbon for this activity.

14 Compost application could lead to changes in soil chemistry, potentially causing trade-offs between sequestration benefits and plant biodiversity. We therefore recommend a prioritization of compost application on highly disturbed areas until evolving science provides clear guidance on how to avoid impacts to biodiversity.

15 In addition to the maps included in this report, tools from the San Francisco Estuary Institute, such as EcoAtlas, can be very helpful in making planning decisions at the local level.

16 In some cases, restoring wetlands may cause near-term emissions from methane. The timing of reduction benefits for wetland restoration is a topic of ongoing research (Petrescu et al. 2015).

17 "Climate impact protection" refers to some of the protections provided by the NBS reduction activity.

18 "County climate action" refers to counties in the specified region that either have a climate action plan or are in the process of developing one.

19 These California climate investments were current as of August 20, 2020, and do not reflect an additional $13.17 million that were invested in multiple jurisdictions and could not be clearly apportioned to our selected regions. A cumulative total of $703.78 million was invested in NBS activities (California Climate Investments 2020)

20 State conservancies can be found at https://files.resources.ca.gov/conservancies/.

21 Since transacted offsets may be attributed to reductions in another sector, the State may need to develop a reporting approach to avoid double counting of reductions.

22 The Central Valley is one of the most important wetland bird waterfowl wintering areas along the Pacific Flyway.

23 UrbanFootprint and COMET Planner are other tools that can help counties and regions assess the climate benefits of land conservation and restoration. See table A-2 for links to these and other tools.

24 For more information, see Nature Conservancy n.d. b and Wu et al. 2019.

25 Stewardship Authority and Good Neighbor Authority, which were permanently authorized by the 2014 federal farm bill, authorize the Forest Service to enter into agreements with nonfederal entities for restoration and management activities on federal lands.

26 For more information on ecological forestry, see R. Kelsey's recent "Wildfires and Forest Resilience: The case for ecological forestry in the Sierra Nevada," https://www.nature.org/en-us/about-us/where-we-work/united-states/california/stories-in-california/californias-wildfire-future/.

27 Senate Bill 901 (Dodd, Chapter 626, Statutes of 2018) exempts from the California Environmental Quality Act certain fuel reduction activities on National Forest lands that have been reviewed for compliance with the National Environmental Protection Act. The California Vegetation Treatment Program takes another step by incorporating CEQA compliance with vegetation treatments that reduce the risk of destructive wildfires while protecting nature, people and property.

28 The Newsom Administration and the Forest Service recently announced a joint state-federal initiative to reduce wildfire

risks, restore watersheds, protect habitat and biological diversity and help the State meet its climate objectives.

29 An additional eight projects were funded through the California State Coastal Conservancy.

30 At the time of publication, this amount does not include the $1.65 million that MTC has yet to award—and also does not include funds provided by the Coastal Conservancy through state bond funds for other parts of the Bay Area.

31 Plans or tools that reveal the ecological, social and economic attributes of natural lands, water resources, working landscapes, natural infrastructure, recreational lands and other open spaces are known as "greenprints." Greenprints provide a framework to represent and quantify the benefits provided by lands to natural and human communities. These benefits may include the conservation of ecosystem values and functions, hazard risk reduction, water and soil conservation, biodiversity, climate change mitigation and resilience, public health and agriculture economic value. See more at: https://www.conservationgateway.org/ConservationPractices/PeopleConservation/greenprints/Pages/default.aspx.

32 Estimates of carbon sequestration are 129 Mg CO_2 y^{-1} in marsh sediment and 156 Mg CO_2 in standing biomass of marsh vegetation for a minimum of 100 years.

33 For more information on a VMT credit strategy, please see Project Climate at: https://www.law.berkeley.edu/research/clee/research/climate/projectclimate/.

34 Appendix A includes links to tools that are being developed to help "close the tree gap" while benefiting underserved communities.

35 These eight activities include reduced wildfire severity, post-wildfire reforestation, changes to forest management, woodland restoration, riparian restoration, agroforestry, cover cropping and avoided conversion.

36 Fertilizer sales for nonfarm uses were not included.

37 The discount rate, shown in table C-1 at 5%, 3% and 2.5%, is defined as the interest rate used to determine the present value of future cash flows.

38 The CPI inflation factor used was 1.23.