1757 Expert Advisory Committee (EAC) Recommendations for Implementation Targets for Natural and Working Lands (NWL) Sector Climate Actions

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*Dr. Steenwerth and Dr. Brigham provided input and exchanged scientific information regarding public lands and carbon sequestration. Their participation was confined to providing information and input regarding scientific factors relevant to carbon storage and other scientific matters related to natural and working lands and does not reflect USDA or NPS agency endorsement. It did not involve disclosure of non-publicly available information or commitments regarding agency resources. Dr. Steenwerth and Dr. Brigham did not provide specific policy recommendations or endorsements regarding how carbon targets might be achieved and did not comment on any matters of financial or other policy matters beyond scientific input regarding carbon targets. Moreover, Drs. Steenwerth and Brigham specifically did not participate in any decision making in respect to financial / funding matters, or provide any recommendations related thereto. Additionally, participation was nonpartisan and should not be interpreted as endorsement for any party or activity.

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Executive Summary

The Expert Advisory Committee (EAC) finds that the state can achieve reductions of 250-400 MMT CO_2 in 10 years from the Natural and Working Lands) NWL sector. This will require focused action and investment, but at a notably lower cost-per-ton of reductions than from other emissions sectors. The core approach that should be followed across the sector is to significantly increase the management, restoration, and conservation of natural systems function at the landscape scale. This requires both focusing development in already developed areas while limiting conversion of land use and land types and changes in resource management to achieve carbon gains and climate resiliency. The actions recommended herein will lead to substantially lower CO_2 emissions, as well as significantly reducing other climate risks such as catastrophic fire, floods, and biodiversity losses. In addition, these actions have the potential to better serve underserved communities through improving urban living conditions as well as living and working conditions for farm and other rural workers. These actions will also be fundamental to enhancing water supply and security across the state. Investment in the NWL sector should be commensurate with the gains made in reducing CO_2 levels, increasing new investment in the sector to at least $10 billion over the next 5 years.

Summary

California has a powerful and previously untapped tool to deploy in climate action: the natural carbon sequestration capacity of its vast and diverse natural and working lands. By restoring and conserving these, the state has an extraordinary opportunity to vastly accelerate meeting its carbon dioxide (CO_2) and other greenhouse gas (GHG) pollution reduction goals established under SB 32, the Global Warming Solutions Act. The actions that will increase durable carbon sequestration on these lands will also be instrumental in securing its future water supplies, protecting its globally outstanding biodiversity and improving the resilience, health and quality of life in frontline, underserved and vulnerable communities. Actions recommended under this report can achieve at least 250-400,000,000 tons of CO_2 reductions in the next 10 years, more than any other emissions sector. Implementation of these recommendations will also reduce multiple climate risks, from catastrophic fire to floods to biodiversity loss, and improving working and living conditions for farm and other rural workers, underserved communities and dense urban areas.

The EAC considered seven land types and uses: Forests, Developed Areas, Agricultural Lands, Deserts, Wetlands and Blue Carbon, Shrublands, and Grasslands. Every area has gains in both emissions reductions and climate benefits. Some, such as with forests, will yield substantial and immediate gains (in the hundreds of millions of tons in 10 years). Other land types, such as developed areas or agricultural lands, may result in smaller direct emissions reductions but also yield significant indirect emissions reductions that are credited to other, fossil fuels-based sector emissions reductions. that will be made. All have gains that can be made in the near term. Additionally, this sector includes the least costly, most near-term gains that can be made with relatively minimal disruption to economic production.

Across all the working groups on the 7 land types and land uses, certain recommendations were universal. The most important emphasis is to act at significantly increased pace and scale, to restore, conserve and manage for natural systems function across landscapes and land types, integrating short term restoration with long-term conservation, and linking working and natural lands to support climate resilience and enhanced, durable natural sequestration. We recommend actions to reduce or stop conversion of both working and natural lands for other uses as well as changing how these resources are managed. This marks a fundamental shift in strategy and focus for effective climate mitigation and adaptation from the NWL sector. This strategy is to underpin naturally resilient systems that can weather climate change stress and store more carbon more effectively than fragmented landscapes and ecosystems. It calls for conservation that protects and supports landscapes and ecosystem function and resilience at scale–such as for watershed and habitat function--rather than on protecting special and unique individual places per se.

Other common themes found in the recommendations across all sectors emphasize actions that support and use climate resilient native species that are adapted to specific regions, limiting soil disturbances, focusing development in already developed places. Conservation is an essential climate strategy not only for rapidly disappearing land types such as shrublands and wetlands, but also to restore and keep functional, large landscapes of forest, grasslands, and farmlands. Additionally, the Committee's recommendations follow the principle of ensuring multiple climate adaptation and mitigation benefits inclusive of, but not limited to, achieving the state's carbon targets. In all cases we sought to also embody the goals of a Just Transition, help fulfill the state's 30x30 and Water Plan goals, and fulfill the target of reducing climate risks, such as heat impacts, wildfires, and floods.

As with reducing emissions from other sectors, some modification of "business as usual" resource management is needed, and investment is necessary to support the transition to management approaches are that less carbon-intensive and more carbon-sequestering. However, the modifications recommended here are all known, proven and practical approaches, not requiring the development of new or proprietary technologies.

The actions in the NWL sector can deliver more emissions reductions more immediately and durably for less expense than in any other sector. As such, they merit a similar level of investment and focus as for the other major emissions sectors for the scale of benefits to be achieved. The EAC recommends investments in the NWL sector of at least $10 billion over the next 5 years with a target of ensuring emissions reductions of 250-400 MMT CO_2.

Introduction

AB 1757 (Rivas 2022) recognized that gains in the natural and working lands (NWL) sector are both essential and complementary to those in the energy, transportation, and manufacturing sectors. The bill directed the California Natural Resources Agency and the California Air Resources Board to establish an Expert Advisory Committee (EAC) to inform and review modeling and analyses for natural and working lands, to advise state agencies on implementation targets, strategies, and standardized accounting, and to provide recommendations on addressing barriers to efficient implementation of climate action in natural and working lands. The EAC's initial responsibility was to recommend targets, implementation actions, strategies, and approaches to meeting said targets by November 2023, in order to help frame recommendations by the state to the Legislature in January 2024. Recommendations on modelling, analyses and accounting will be developed in 2024.

The EAC set guiding principles on its work agreeing to build on the current work already adopted by the State, such as the Climate-Smart Land Strategy and Climate Adaptation Strategy. Importantly, we prioritized scalable, proven, near-term "no-regrets" actions that are currently available with exiting tools and affordable technologies, and will result in gains for both carbon emissions reductions and climate resiliency in the next 5-10 years.

We considered both the direct and indirect CO_2 emissions benefits in our evaluation. In all actions, we included considerations of co-benefits, trade-offs, and potential limits. Our recommendations also include specific vegetation types and regional considerations in addition to state-wide implementation targets, identifying regionally based opportunities. The EAC process committed to the following Guiding Principles:

- Emphasize equitable/inclusive processes that address the needs of marginalized, underserved and/or frontline communities.

- Focus on implementation targets that meet or exceed the State's carbon stock target (no more than 4% reduction in stocks from 2014) and have the potential to accelerate achieving total reduction goals of AB 32 *with a climate lens*. Within that focus, we:
    - Prioritized specific foci that are most likely to help meet/exceed these overall targets; identified ecosystems/land types, regions, and
    - Developed strategies and actions to reach implementation targets.

- Implementation targets build on the current work delineated in the Climate Smart Land Strategy and Adaptation Strategy and identify gaps therein.

- Consider co-benefits, trade-offs, and potential limits when recommending implementation targets.
- Prioritize scalable, near-term (within next 5-10 years) “no-regrets” actions that are well vetted and have been identified in CSLS.
- Identify, as feasible, other GHGs, like methane and nitrous oxide, recommending actions that may be taken to address these as well.
- Emphasize regional approaches and equitable, inclusive processes that address the needs of marginalized and/or frontline communities.

Overarching and Cross-Cutting Recommendations

Across all the working groups on the seven land types and land uses, certain recommendations were universal. Some of these recommendations address *how* achieving the targets should be approached, while others focus on *what* the actual target recommendations should achieve. The former fundamentally address social and cultural concerns. The latter address ecosystem function and desired climate resilience outcomes. The context and nuances of how these are to be applied and achieved are found within each section of the report.

Social and Cultural Approaches should address:

- **Equity.** Increase engagement, self-determination, and action in frontline, disadvantaged, low-income communities, support Just Transition, as defined by the International Labour Organization.

- **Tribal Engagement.** Increase engagement and consultation with State and Federally recognized Tribal entities (Governments, NGOs, Collectives, etc); increase utilization of Indigenous Knowledge and Traditional Ecological Knowledge, and support Tribal-led conservation and restoration priorities.

- **Workforce Pipeline.** Increase essential pipelines/supplies for workforce, especially from underserved and lower economic communities. Work with the statewide system of Community Colleges and other appropriate state institutions to develop a suite of regionally appropriate skills-based jobs in climate adaptation management (e.g. habitat and ecosystems restoration, organic agriculture, brownfield restoration, urban farming, etc.).

- **Seed Sources.** Increase the breadth and capacity of production of appropriate seed sources, especially native species and appropriate cover crop species for climate resistance

- **Technical Assistance.** Increase technical assistance for climate-smart resource management.

- **Community Engagement.** Increase engagement of local communities in education, project design, and implementation.

Ecosystem Function for Climate & Carbon Outcomes will require increases in:

- **Conservation.** Substantially increase conservation of relatively intact working and natural lands. Maintain or increase the overall amount of relatively natural lands (forests; wetlands, grasslands, deserts and shrublands/chapparal). Maintain or significantly reduce land use and land type losses limiting all land types conversion to development and fragmentation and land use conversion except where restoring more naturally functioning systems.

- **Integration of short-term actions with long term implementation**. Build on benefits of near-term restoration (such as fire resilience, riparian, forests and meadow systems restoration, etc.) to assure enduring impact, especially through working lands conservation easements on private lands (e.g., forest, grass, and agricultural lands).

- **Restoration of natural systems emphasizing climate resilient native species.** This practice should be implemented across and within all NWL segments, helping to bridge transition zones, promote connectivity and support biodiversity targets as well as reduce water and energy needs for long-term revegetation success.

- **Support for natural systems management** to reduce disturbances and enhance resilience.

- **Reductions in soil disturbance** across all land types as this leads to soil carbon and moisture loss and reduction in soil microbial functions essential for productive healthy soils.

- **Restoration and conservation of transitional zones to enable adaptation under climate change** (such as in wetlands and shrub systems) and cross-cutting habitat types: i.e., riparian zones; farmland fringes; urban to sub/peri-urban corridors to working-natural lands.

Agriculture

SECTION 1. Outline scope and importance of land sector

Agriculture provides a fundamental service to society and the environment. It must retain flexibility to achieve these goals and provide for food production and food security (Porter et al 2014). Agriculture faces many climate and labor challenges over the coming 10 to 50 years (Steenwerth et al. 2014). Agriculture can provide mitigation for our changing climate, but the EAC acknowledges the need for investment in adaptations that maximize agriculture's resistance to climate stressors and maintain food security.

In the last two decades, California agriculture has effectively undertaken a broad effort to both adapt to climate stressors and offer greenhouse gas (GHG) mitigation and carbon offsets. Here, GHGs include carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Growers in California use cover crops, sown directly or using resident vegetation, and apply compost to meet crop N demand (Steenwerth & Belina, 2008; Zhu et al. 2013; Zhu-Barker et al., 2018, 2019). Perennial crop growers adopt these practices more broadly compared to row crops, due to economic restraints. Through successive use (i.e., annually), cover crops and compost can provide increases in soil carbon (C), nutrient use efficiency and retention, water holding capacity and microbial activity (Steenwerth & Belina 2008a,b; Kallenbach et al., 2010; Zhu et al. 2013). Advanced micro-irrigation practices have led to dramatic reductions in GHG emissions and nutrient loss, and improved crop nitrogen use efficiency (Khalsa et al., 2017, 2020, 2022; Schellenberg et al. 2017; Wolff et al., 2017; Nichols, 2023). For example, N_2O emissions have been reduced to below baseline values in old flood irrigation approaches (Zhu-Barker et al. 2019). Still, blended irrigation designs are needed to manage leaching, alley and wheel track germination for cover crops, and infiltration for groundwater recharge. Even in rice, which utilizes flood irrigation for production, GHG emissions have been significantly reduced due to increases in productivity and changes in water management (Linquist et al., 2015).

Several decadal field experiments in California have been completed on effects of compost, cover crop and tillage on soil C. No-till or conservation till shows mixed results with total soil C gains no different or lower than tilled soils with or without cover crops (Koch 2023). No-till soils do enrich surface soils with C compared to tilled soil, increasing infiltration and potentially water holding capacity, therefore providing essential adaptation measures to ensure food security (Mitchell et al., 2017). Yearly compost application in annual crop production, regardless of tillage, can increase soil C by about <0.1 to 0.2 t C per hectare per year (Poudel et al. 1999; Tautges et al. 2019). Compost applications on soil C have mainly been studied in organic production systems and can increase soil C up to 0.3 t C per hectare per year. All soil C gains occurred primarily within the first 10 years, and permanency requires perpetual and consistent practice implementation. The C sequestration values in these experimental studies are lower, sometimes up to 10x lower than some model predictions. This is likely due to models predicting maximum potential when in practice, climate, grower decisions and economics control the biophysical potential to sequester soil C. The latest preliminary unpublished results suggest that soil C in the above decadal experiments may begin to slightly decline from maximum levels after 15 to 20 years of management to increase soil C, likely due to reaching a new equilibrium and or impacts of increasing mean annual temperature from our changing climate. The results strongly suggest that current model predictions need to be reassessed by incorporating new data, climate impacts and changes in irrigation management, especially when irrigation efficiency may lead to lower microbial contribution to soil C maintenance (Griffin-LaHue et al., 2023).

The reduction in GHG from micro-irrigation approaches contributes significantly more to reducing 'global warming potential' (GWP) than the other practices discussed above. The magnitude of the above practices to reduce GWP can be expressed as 'yield-scaled global warming potential' (YS-GWP). YS-GWP is meaningful because it includes agriculture's provisioning services and scales GWP with respect to crop yield providing value to increasing crop nitrogen use efficiency and soil C gains (Zhao et al. 2019).

Given agriculture's essential role, we must flip the view from agriculture as a source of C offsets, especially in California's semiarid Mediterranean climate, to one that reduces its GHG emissions to the greatest extent possible relative to crop production. California agriculture can further expand practices that build soil to support crop productivity. Such practices also build soil C for soil health outcomes, improve water use efficiency and nitrogen use efficiency, and can significantly improve environmental quality. However, the State's Sustainable Groundwater Management Act (SGMA) may require some croplands to go fallow due to water limitation, resulting in the likely loss of soil C with the magnitude dependent on area and frequency of fallowing. These outcomes support human and animal health, which are existing priorities of the state. In fact, the CDFA Healthy Soils Program, which facilitates meeting the AB1757 goals in agriculture, specifically values soil health for its role in supporting bioproductivity, air quality, water quality, animal health, *and* public health in addition to building soil C.

SECTION 2 & 3 (combined). Recommended actions, strategies, and implementation target(s)

Implementation Target 1. We elevate the need for enhanced social dialogue around Just Transitions in California agriculture. This priority crosses all Implementation targets identified for Agriculture.

The International Labour Organization defines a Just Transition as "...greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind. A Just Transition involves maximizing the social and economic opportunities of climate action, while minimizing and carefully managing any challenges – including through effective social dialogue among all groups impacted, and respect for fundamental labor principles and rights."

The consequences of decisions and actions we take now are accrued generationally, and evaluation of these goals and their implementation must occur with that perspective. As such, we recommend strengthening the capacity of local communities to define, adapt, and implement the strategies to their holistic context. We don't presume to understand the nuances or complexities of the socioeconomic ecosystems in which the agricultural decisions and actions that impact climate resilience are made but we are confident that the most efficacious solutions lie proportionally within the radius proximate to those communities. We advance the report 'Guidelines for a just transition towards environmentally sustainable economies and societies for all' by the International Labour Organization and their associated Just Transition Policy brief series (October 2022 - June 2023) as guides to accomplish Just Transitions within Nature-based Solutions.

Pathways, Strategies, and Actions.

Build and enhance integrated technical and communication networks spanning local to statewide capacities. Prioritize needs of the community and local farming systems in order to maintain innovation and preparedness of agriculture to our changing climate. Develop and enhance regional innovation and service centers to allow for local capacity building to adapt and mitigate climate change as well as expand access to land tenure and equity within under-resourced or under-served agricultural communities. To expand inclusion, offer agricultural technical assistance programs that are accessible and culturally relevant, including for Indigenous language speakers.

- Address barrier to farmland access and land tenure by supporting community-led land access projects; develop policies that ensure all farmers have good faith options to renew their lease agreements under just cause termination; prioritize inclusion of historically underrepresented farmers equal to/exceeding their demographics in CA; support access to credit for young, BIPOC, small, and diversified farmers; and support business technical assistance for young, BIPOC, small, and diversified farmers. Please refer to Chapman et al. (2023) for additional information.

- Reduce the use of pesticides, especially by prioritizing removal of the most toxic chemistries. To do so, we elevate reducing the use of Highly Hazardous Pesticides in line with the EU Farm to Fork target, CARB EJAC's recommendations and the Sustainable Pest Management Roadmap. Not only do these three components act as a pathway to reduce pesticide usage and advance integrated pest management practices, they also serve as a road map on how to build capacity for equity, communication and community organizing from local to state levels. Outcomes of reducing use of pesticides include enhanced environmental quality, avoided GHG emissions and energy usage during production of petroleum-based synthetic chemistries, and improvements in pollinator health and public health (Schneider et al. 2023). To support extension and additional research and development of approaches to reduce agricultural pesticide usage, utilize an increase in the pesticide mill fee; state-level, public climate change-related funding sources; and the state's General Fund. Progress can be measured via DPR's required pesticide use reporting system, but tracking and reporting the toxicity of pesticides should be prioritized. We argue for use of the indicator 'Pesticide Load', which documents the development and use of the indicator 'Pesticide Load' (PL) to reflect the ecotoxicology, human health and environmental fate of pesticides rather than just treatment amount and frequency (Kudsk et al. 2018). This indicator is expanding in European agriculture, and the work by Kudsk et al. (2018) and Lewis et al. (2021) documents implementation in Denmark and the United Kingdom. Furthermore, Schneider et al. (2023) present content addressing myths and strategies to reduce by 50% the use and risk of chemical pesticides by 2030 and reduce by 50% the use of more hazardous pesticides by 2030, as part of the European Union Green Deal – a target that has also been identified by other agricultural stakeholders in California.

- To meet the goal of Just Transitions, provide support for community-based research with farmworkers to inform an economically equitable pay structure for farmworkers and safeguard sustainability and accessibility for those working in organic and agroecological farming, at all points in the supply chain. Include an analysis of farmworker access to organic produce for personal consumption.

- Focus on integrated engagement among the local climate action planning and target-setting processes with the state-level climate planning processes as a critical step to build this capacity.

- Provide financial support for participating organizations to engage in these processes needed to build coalitions among community members and various institutions. This support should include covering travel and hourly wages for attendance at meetings to offering funds for administration and coordination of this effort to multiple entities involved in the process.

Implementation Target 2. Protect farmland and avoid conversion out of agriculture to maintain C stocks, enhance environmental benefits, and facilitate Just Transitions for communities in agricultural regions. By 2050 move 100% of CA farmland into equilibrium status, where all losses due to land fallowing or urban development result in rehabilitation to a more climate-resilient ecosystem category, in the case of the former, or reclamation of unused urban space for agricultural or park utilization, in the case of the latter.

Maintaining agricultural production is a high priority to avoid GHG emissions and C loss that occur as a consequence of land use conversion to urban systems (Jackson et al. 2012). Conversion out of agriculture is a true concern for California, given the many competing interests for land conservation and development, and various policies like SGMA. Agricultural land conversion has been tracked by the Dept of Conservation using the Farmland Mapping and Monitoring Program, and additional conserved acres can be tracked via new conservation easements and federal programs (e.g. CRP).

Pathways, Strategies, and Actions.

Fund Department of Conservation at $1 Million per year over 2 years to initiate county task forces to develop holistic land-use goals that prioritize preservation of agriculture and land restoration.

We recommend that the task force identify and implement democratic and community solutions to directly address economic drivers of land conversion. Also, offer financial support to train and employ planners to create processes and objectives in support of a task force plan that incentivizes generational in-fill development.

- Collectively fund SALC and California Farmlink at $500,000 annually over 2 years to build a coalition of Land Trusts, Tribal Groups, farmers and community interests to define best and most promising practices in agricultural Conservation Easements (CE).

- Historically simple CE plans are now being expanded to unambiguously create and integrate multiple layers of environmental and social benefit (see MALT, POST, AFT). The long-term impacts of the earlier one-dimensional CEs often lacked equitable allocation and rigorous examination of the impact on land conversion and local agrarian socioeconomics. Newer models should be paired with thorough analysis of eventualities and prioritize land and credit access for young, BIPOC, small, and diversified farmers with the highest exposure to climate risks.

- Fund CDFA $500,000 annually over two years to identify farming systems' economic and agronomic resilience as a means to increase the near-term financial viability and decrease long-term risk of keeping farms intact and functional.

  We recommend the following categories of inquiry: 1) Support for development of crops, practices, and systems that will be better adapted to our region in the next 25 years. Examples of emerging systems include alley cropping, livestock integration, polycropping and agrivoltaics. 2) Study of the impacts of these systems on farms, on the state's agricultural economy, and on co-benefits. Specifically focus on capacity for optionality in response to high variance water availability and increasing heat burdens. 4) Strengthen brand identity and market support for California farmers by leveraging existing competitive advantages, specifically; soil health, animal welfare, and social fairness.

Implementation Target 3. Expand farm-edge diversification to support innovation and utilization of liminal spaces in farming systems, which all offer increases in landscape C storage and ecosystem services. Benefits of this diversification include cooler water in riparian areas, reduced flooding and loss of nutrients from the farm to freshwater, beneficial increases in habitat, resilience of small scale farming endeavors, and standing aboveground C and soil C on farm edges. Hedgerows also offer windbreaks and beneficial insectaries.

Pathways, Strategies, and Actions.

- Increase expansion of cultural crops and medicinal plants through germplasm development, technical assistance, market development and other programs for diffusion of innovations. Marginal land is often the only space available to indigenous and traditionally unsupported demographics.

- Increase the capacity to develop and produce regionally suitable plants (germplasm) by climate, region and intended use. Develop infrastructure for scaled regional plant nurseries and invest in workforce development for nursery production of suitable, native plant material. This dovetails with urbanscapes' need for regionally suitable plants to restore riparian areas, park edges and swales to filter and direct wastewater.

- Support agroecosystem functionality through farm edge diversification on the conservative estimate of 381,000 acres of farm edges in California; target 100% of these edges by 2040. This value does not include available area along gullies, canals, drainage and roadsides.

- Provide investment and grant programs to support: 1) grower access to plant material and capital to implement and sustain these practices and 2) regional technical assistance for riparian forest restoration and production of new plant material. Technical assistance providers include UCCE, NRCS, CCC and RCDs.

- Allow for tax break on area that is restored to riparian forest, cultural crops or hedgerows.

- Assess progress by remote sensing techniques, and via mandated reporting through extramural funding mechanisms.

Implementation Target 4. Expand opportunity for organic agriculture to 100% of farming operations and 20% of statewide farming acres by 2045.

The blended metric focuses on the number of farming operations for a number of reasons that are directly and indirectly related to our GHG goals. We argue that this will allow for community-based accountability in terms of local food security, farmworker health and well-being, food miles, local economics, and land-use optimization. It will compel agency programs to be inclusive of diversity of farming operations and stakeholders in a given region by not only prioritizing acreage. This goal allows us to meet AB1757's target of addressing social justice and equity, as well as climate change concerns, as communities where organic agriculture is expanded will have reduced exposure to pesticides (Pesticide Action Network, 2023 and scientific references therein).

Pathways, Strategies, and Actions.

- Fund CDFA at $25 million annually through 2045 to provide wrap-around technical support for the transition to organic agriculture and expand cost-sharing programs that support this transition for 100% of socially disadvantaged farmers or ranchers by 2025. If funds remain, funds will be distributed to limited resource farmers or applicants, and lastly, to remaining farmer applicants.

  Wrap-around services should be delivered by coalitions spanning local to statewide capacities in order to provide:

  1. Agronomic, certification and restoration advising support for the transition to organic, climate-smart practices, and community and regionally relevant systems as well as technical assistance to access CDFA or USDA programs and technologies.
  2. Community services to support; health care, translation, mental health, childcare and education, and co-operative organizing.
  3. Capital and land access (especially good faith options to renew their lease agreements under just cause termination) and business consulting.

- Invest $1 million annually over 10 years (from 2025-2034) to expand farmer organizing programs which reduce barriers and risks for under-resourced farmers to transition to organic farming practices.

  Primarily, we refer to AB-552 Farmer Equity Act of 2017: Regional Farmer Equipment and Cooperative Resources Assistance Pilot Program. AB-552 was presented to the Governor on 9/20/23 and pending approval. Secondarily, we highlight the work in Fresno…

- Facilitate the development of climate-adapted Organic crops and inputs: Invest $40 million annually in UC Cooperative Extension and County Farm Advisors for applied research and outreach led by a holistic strategic plan by 2030 to develop and enhance regional innovation and service centers for local capacity building to adapt to organic transition and mitigate climate change impacts.

    a. Increase capacity for seed and plant production of climate-adapted cash and cover crops, and medicinal plants through germplasm development, on-farm trials, technical assistance, market development and other programs for diffusion of innovations.

    b. Increase capacity of compost production at local hubs. With increased production capacity from the diversion of organic wastes from landfills and manure sources anticipated with AB 1383 (state's compost mandate), compost availability will still be lacking and supply only 3 to 4 tons compost per acre annually (8 to 16 tons needed annually) for the goal of increasing organic cropland by 20% (2 mil acres) of total cultivated land. This shortfall will result in less opportunities to improve soil health for remaining croplands and other uses such as landscaping and urban gardens, nurseries, roadside stability and restoration (CALTRANS) and grasslands.

    c. Development of affordable formulations of organic fertilizer and develop regional and local sources of feedstocks, such as hydrolyzed protein and plant meal sources to reduce reliance on out of state and foreign sources that would offset gains in target mitigation plans.

- Develop new markets and expand existing ones for organic products to avoid depressing produce values.

    Prioritize efforts initially like 'Farm to School' and 'Farm to Institutions' such as hospitals, prisons, elder care, group homes, and CALFire. Establish a permanent CDFA Farm to School Program where at least 20% of procurement funds are targeted toward organic producers; and establish and implement a state procurement program prioritizing purchase of CA-grown organic food by 2028.

- Identify new resources and investment $3 million annually for 3 years to to integrated pest and weed management (e.g. see material on Sustainable Agriculture Research and Education, wsare.org). Expand research programs and number of publicly-funded, technical service providers, to support the transition to organic agriculture. Incorporate IPM and related farming practices into CDFA-HSP, and refer to the Sustainable Pest Management Roadmap for how to expand these approaches to support organic farming.

Implementation Target 5. Increase access to soil building practices, and continue Investment in integrated fertilizer, irrigation, and soil fertility management practices to reduce N_2O emissions and build soil organic carbon*.*

The use of compost, cover cropping, and crop rotations allows for improvements in soil properties prized for increasing crop productivity. Building soil organic matter, often reflected by total organic carbon content, is a key to enhancing functions like soil nutrient retention. Specialty crop growers, such as wine grapes and almonds, tend to have a higher adoption of cover crops compared to annual or row crop growers. Cover crop adoption in specialty crops is as high as 46% (Gould and Rudnick 2018). We identify these practices as 'no regrets', but we reveal gaps that need to be addressed to scale them across California's agricultural system.

Research studies reveal that after practice implementation, most soil C sequestration occurs in the first 10 years, thereafter soils reach a new equilibrium. Once a new equilibrium is achieved soil C may slightly decline due to climate impacts. Once meeting this condition, soil C building practices must remain in place to maintain C permanency. This concept of C equilibria and permanency must be built into the scoping plan, private business models and programs that engage growers to provide this service to others. Who will bear the cost of maintaining C permanency? As such, we prioritize adaptation over mitigation in agriculture, especially since practices such as no-till, compost and cover crops build soil health and food security.

Pathways, Strategies, and Actions.

- Increase investment in CDFA HSP and collaboration with NRCS EQIP to build upon the 350,000 acres of cover crops in California agriculture reported in the 2017 Ag Census from USDA-NASS.

- Increase capacity for seed production and for climate-adapted cover crops; supply chain is extremely limited by available seed type and volume, with currently about a ⅓ of growers indicating issues with obtaining seed.

- Increase capacity of compost production at local hubs to reduce the transportation costs and fuel emissions, and increase local access to compost per SB 1383. Continue investment and permitting of compost facilities.

- Provide technical assistance, incentives and service to growers not yet utilizing these programs and/or technologies. Further, invest in programs like those described in AB-552 Farmer Equity Act of 2017: Regional Farmer Equipment and Cooperative Resources Assistance Pilot Program to facilitate use of these practices.

- Review and collate existing data sources for soil C and GHG emissions. Use this assessment to identify where the gaps are in data sources to develop an empirical approach to assessing practices that reduce GHG emissions and increase soil C.

- Assess the success of these practices by developing a long-term monitoring network to assess soil C content, nutrient retention, nitrous oxide emissions and nitrate leaching based on practices that are implemented by growers across regions, soil types and climates. This will reduce the high uncertainty surrounding the modeled values used to quantify potential soil C storage potential and nitrous oxide emissions. To this end, conduct an external assessment of available data sources for soil C and GHG emissions to assess where gaps need to be addressed.

Deserts

SECTION 1. Outline scope and importance of land sector

The Mojave, Colorado, and Great Basin Deserts of California are considered globally significant areas that support a high diversity of plants and wildlife as well as providing numerous ecosystem services for humans, including municipal, commercial and recreational opportunities. This region is the ancestral homeland of tribal communities and is a unique and sensitive habitat with rich cultural and natural histories.

Various California state assessments have addressed the characteristics and importance of Californian Desert regions and we briefly summarize those here. First, the 2022 California NWL Climate Smart Land Strategy considers lands with <10% cover as sparsely vegetated lands; this definition covers 10% of the state (10.2 million acres), and includes desert, beach and dune areas with less than 10% vegetation cover, bare rock landscapes, and areas covered in ice or snow such as those above the tree line in mountainous regions. Second, California's Fourth Climate Change Assessment (2018) and the 2022 California Climate Adaptation Strategy both characterize the inland desert region as encompassing the Mojave and Sonoran deserts in the southeast corner of the state, including all of Imperial County and the desert portions of Riverside and San Bernardino Counties. This region has the largest amount of federally protected lands in the state: 7,448 square miles of National Parks and Monuments, including important wildlife refuges and unique ecosystems. In the Mojave Desert, there are approximately 210 species of plants that are found nowhere else on Earth. There are many iconic plants and animals that would benefit from increased conservation investments, including Joshua trees, threatened desert tortoises and Mohave ground squirrels, desert bighorn sheep and golden eagles. The homelands of 12 different tribes are located in the region; overall this area has about 1 million inhabitants, with 85% of those residing in urbanized areas including the Victor Valley in San Bernardino County, the Coachella Valley in Riverside County, and the El Centro Metropolitan Area in Imperial County.

The 4th Climate Change Assessment estimates that future development will likely take place within and amongst these urbanized areas. Agriculture is the primary driver of the Inland Deserts region's economy, followed by tourism (largely to the Coachella Valley), and is also an important region for transportation, logistics, and warehousing, and real estate development—an industry that includes housing and renewable energy. Agriculture in the valleys is nearly completely irrigation-dependent, and the already-high water demand in the region will likely increase with rising evapotranspiration rates under a warmer climate. Solar farms, largely built on federal lands in the Colorado Desert of California, currently represent one of the densest areas of solar development in North America. Imperial Valley also contains some of the largest lithium deposits in the world. Solar and lithium extraction have been forecasted to increase significantly in the region due to further grid electrification, but with potentially significant and unwanted impacts on already strained water resources, carbon storage, biodiversity, and environmental and public health.

California's deserts store nearly 10% of the state's carbon. This carbon is stored underground in the soil and root systems, and above ground in biomass. Research has shown that the construction and operation of large-scale solar and other extraction projects scrape the desert bare of vegetation across thousands of acres, disrupting ecological processes and leads to habitat fragmentation, and impact gene flow and prevents movement in species such as bighorn sheep, deer, and the desert tortoise (Lovich et al. 2011, Tawalbeh et al. 2021). Further, lichens, along with bacteria and moss, form a biological soil crust that acts as a protective barrier for desert ecosystems, helping prevent erosion, creating a nutrient-rich growing environment and increasing water retention (Finger-Higgins et al. 2022). Surface-disrupting projects impact these natural resources and sometimes with global consequences impacting hydrologic regimes and freshwater biogeochemistry, marine resources, and human health (Pointing and Belnap 2014). Further, the disturbance notably threatens carbon-sequestration capabilities in these regions (Allen et al. 2023). Undisturbed desert land can sequester carbon over long timescales. Careful consideration of solar development and lithium extraction, as well as other urban, agricultural and industrial installations, is critical to avoiding potential long-term damages to the carbon sequestration capacities, as well as significant threats to the conservation of water, biodiversity, ecosystem services, and cultural history associated with these regions.

Uncertainties around these ecosystems exist around the monitoring and modeling of carbon stores. Some unknowns concern the pulse-driven nature of desert biogeochemistry and nitrogen fluxes can be substantial, and also difficult to capture. Further, inorganic carbon is a critical carbon pool not currently adequately captured in carbon sequestration estimates in desert region ecosystems. The desert’s carbon storage process differs significantly from more widely understood sectors such as forests, grasslands, chaparral, and wetlands (Allen et al. 2023). More research is needed to address these areas.

SECTION 2. Recommended actions, strategies, and implementation target(s)

Given their carbon storage capabilities, conservation of large, intact desert areas (e.g., those without disturbed topsoils and/or an intact caliche[1]) and restoration of sensitive habitats could have a high return on investment for climate mitigation. Care should especially be taken in recognizing Death Valley (Sierra Nevada – East sub ecoregion) as a desert ecosystem that is unique and separate from others in the Sierra Nevada ecoregion. Importantly, local stakeholders, tribes and desert communities should be part of the decision-making process to ensure that those groups disproportionately impacted by conservation (or other) efforts in this ecoregion are well represented.

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[1] Caliche is a hardened deposit of calcium carbonate that cements together other materials, including gravel, sand, clay, and silt (Schlesinger 2005)

Conserving California's intact landscapes (DeGagne et al. 2016) and avoiding further disturbance is a high priority. The CARB 2022 Scoping Plan for Achieving Carbon Neutrality recommends cutting land conversion of deserts and sparsely vegetated landscapes by at least 50 percent annually from current levels, starting in 2025. Avoided conversion of sparsely vegetated lands reduces the organic carbon lost from the soil, which is the major carbon pool in this land type. Our recommendations are as follows:

- Aligned with the 2022 Scoping Plan, in order to prioritize short-term carbon stocks, the recommendation is to minimize disturbances (e.g., disruption of topsoil) for sparsely vegetated habitats, the priority action is for no further land conversion aside from the estimated 2,600 acres/per year associated with city-related growth and within perimeters of existing municipal jurisdictions.

- Land conversion occurring outside of the estimated city growth (e.g., new development) is not recommended. If certain land conversion is necessary, appropriate carbon sequestration mitigation, and in addition to prioritization for water, biodiversity and habitat conservation, adequate for timescales relative to desert ecosystems, is required (e.g., carbon credits, restoration, etc.).

- We recommend accelerating the 2022 Scoping plan conservation recommendation of 15,000 acres per year to a minimum of 15,000 acres per year, and a maximum feasible acreage beyond this amount.

- Restoration activities should be targeted toward invasive species removal (e.g., Tamarisk and other species) and restoration of riparian zones in order to prioritize short and long term carbon stocks and important co-benefits for water conservation, biodiversity enhancement and ecosystem health.

SECTION 3. Pathways to reach the implementation target(s)

To achieve the proposed implementation targets provided above, we suggest the following mechanisms. First, increased investment in ongoing state desert and riparian conservation programs can leverage related activities to protect and restore desert ecosystems. These include the Wildlife Conservation Board Desert Conservation and Riparian Habitat Conservation Programs. We recommend that carbon sequestration should become a key priority of these existing programs, including the estimation and measurement of carbon storage associated with each project. To meet the need for renewable energy production, we recommend incentivizing solar development (e.g., photovoltaic arrays or similar) on already disturbed private lands, including rooftop solar opportunities on the already-built environment. Engagement with key stakeholders is of critical importance. At least 12 tribal groups are associated with Californian Desert Regions - preservation of present-day and historical values for these communities must be prioritized. Major landholders in the region include but are not limited to, the federal Bureau of Land Management and the National Park Service, state California State Parks, and agricultural and other commercial representatives. While any further land conversion is not recommended, the selection and siting of any development proposed by these groups must prioritize carbon stocks, biodiversity, ecosystem health, and water conservation.

Developed Lands

SECTION 1. Land type scope and importance

Developed lands, which include both urban and rural components, and cover just 6% of California but house over 94% of the state's population. Developed lands are defined as systems dominated by human development in the form of housing on small contiguous lots, industrial sites, and transportation corridors. This includes communities of over 2500 people, following the US Census Bureau. Developed lands contain a mixture of hardened development (buildings and roads) intermixed with all ecosystem elements (e.g., forests, wetlands), and a suite of unique plant assemblages not considered elsewhere (e.g., lawns, street trees, parks). We address four critical issues.

First and foremost, we address the impacts that developed lands have on climate (e.g., urban heat islands) (Estoque et al., 2017; Ossola et al., 2021; Sinha et al., 2022) and actions (e.g., urban greening) that have significant ameliorating climatic effects (Bowler et al., 2020) as well as social benefit (Pataki et al., 2021). Reducing urban temperatures results in indirect climate benefits through reduced carbon emissions (Nowak et al., n.d.), but also helps to build more livable cities, improve human physical and mental well-being and help redress significant historical social inequities and injustices (Grilli et al., 2020; Kweon et al., 2017; Lin et al., 2018).

Second, we address how developed lands contribute directly to carbon sequestration (Edgar et al., 2021; Nowak et al., 2022b). Here our focus is on urban trees, although other urban greenspaces (parks, gardens, urban farms, green roofing, swales) also sequester carbon.

Third, we address the urban footprint (Thorne et al., 2017). Developed areas, on average emit significantly more carbon than natural and working lands. Addressing climate benefits for all other land cover types entails reducing habitat loss to developed lands.

Finally, we address carbon sequestration and fire safety at the Wildland -Urban interface (WUI) (Calkin et al., 2014; Radeloff et al., 2018). Current best management practices entail fuels reductions along the WUI to enhance fire-safe communities. Managing toward community fire safety will result in short term losses of carbon stocks.

Issues of social equity and environmental justice permeate each of these four areas (Schwarz et al., 2015). Our recommendations focus on strategies to meet California's challenging climate goals as well as to increase social equity and redress past environmental injustices.

SECTION 2. Recommended actions, strategies, and implementation target(s)

Existing guidance from California's NWL Climate Smart Lands Strategy and the CARB Scoping Plan both offer a robust foundation for climate strategies in urban areas, emphasizing reduced emissions and carbon sequestration. However, to maximize climate impact, actions must be prioritized, aligning with both the state's recommendations and our own assessment of crucial needs. We recommend prioritizing four targets to help meet California's ambitious climate targets.

Target 1. Create a *California Urban Greenspace Strategy* by 2030, with on-going tracking toward implementation.

Urban maximum temperatures can vary by several degrees across a city directly as a result of variation in greenspace. Mitigating urban heat islands with a portfolio of strategies (e.g., daylighting streams, green roofs, urban vegetation) can reduce urban energy use. To attain California's climate goals, the state needs a comprehensive evaluation of the capacity to reduce energy usage through urban greening and strategies to achieve this potential.

Target 2. Increase C sequestration target to 50 MMT CO_2 by 2050.

The CARB Scoping Plan model suggests a potential to increase double urban carbon storage by approximately 30 MMT to 50 MMT CO_2 by 2050. Progress toward this goal may be significant in the next 5-10 years, but as trees grow slowly, we expect to see larger benefits closer to 2050. While substantial, this carbon storage is small relative to statewide carbon pools, which suggests that the co-benefits of urban trees should drive implementation planning for urban forests.

Target 3. Reduce expansion of Developed Land to less than 10,000 new acres within 10 years and integrate build-out perimeter planning into general plans.

It is estimated that carbon emissions increase 40-70% through conversion to developed lands. Reducing land conversion is a critical element to natural and working lands contribution to carbon neutrality. California's population is currently shrinking and projected to increase by less than 3% (1.1 million people) by 2050. Smart growth models focusing on infill can accommodate nearly 100% of this growth with nearly no new lands converted to developed lands. These figures suggest a need for cities to integrate long-term perimeter planning into their general plans.

Target 4. Achieve full compliance to WUI defensible space within 10 years.

CARB estimated that coming into full compliance with existing defensible space laws would result in landowners reducing carbon stocks by 4.2 MMtC. We find this to be a plausible and acceptable loss of carbon for the net climate benefit of achieving higher fire safety and allowing fire suppression to increase actions to focused on wildlands rather than defending ill-defended homes.

SECTION 3. Pathways to reach the implementation target(s)

Target 1. Providing climate benefits through increased human well-being and reducing carbon emissions on developed lands can be achieved through strategic use of funds designated to foster a portfolio of urban greening strategies.

The largest urban heat island effects are found in under-served communities (Lehnert et al., 2020; Yeager et al., 2023). Reducing energy usage(Bowler et al., 2020; Nowak et al., n.d.), increasing human health (Pataki et al., 2021; Sinha et al., 2022) and increasing equity (Mullenbach et al., 2022; Nowak et al., 2022a)are all achieved through urban greening programs. California's Nature-Based Solutions (California Resources Agency, 2022) provides more priority solutions for urban areas than any other ecosystem, including 14 recommendations that directly relate to urban greening, with 4 of the remaining five being indirect benefits associated with urban greening. What is lacking is a clear evaluation of how different strategies should be deployed to maximize climate and social benefit. Pathways to reducing urban heat island effects and increasing well-being for the 36 million urban residents in California must start with a plan.

- Create a comprehensive and spatially explicit California Urban Greenspace Strategy for more livable California urban areas through strategic deployment of resources to reduce urban heat island effects to:
    - Reduce Urban heat island effects to:
        - Reduce social inequities
        - Reduce emissions through energy usage.
        - Minimize adverse impacts on water conservation strategies
        - Integrate restored urban brownfields in climate-smart development
    - Provide Jobs and technical assistance through:
        - Training programs for technical advisors for the portfolio of urban greening strategies
        - Jobs in urban greening
    - Reduce ancillary climate and health impacts through:
        - Increasing healthy soil practices
        - Reduce pesticide and fertilizer usage in urban green spaces

- This California Urban Greenspace Strategy should recognize the multiple benefits of reducing urban heat island effects through urban greening. These may include:
    - Positive human health consequences of green and blue space.

    - Impacts of exposure of humans to greenspace on mental well-being and happiness.
    - Reduced transportation energy costs associated with providing recreational spaces in close proximity to people.
    - Increased educational opportunities on energy and nature through urban greenspaces.
    - Create comprehensive community engagement programs to partner in urban greening.

- This California Urban Greenspace Strategy should evaluate the comparative benefits of the portfolio of greening strategies, including:
    - Parks
    - Green schoolyards
    - Urban gardening and farming programs
    - Urban roadside vegetation management
    - Urban vegetation including
        - Street and yard trees
        - Lawns, gardens and yard shrubbery
    - Green roofs and other green infrastructure

- This California Urban Greenspace Strategy should evaluate the potential of maximizing greenspace benefit through a focus on historically under-served communities.

- This California Urban Greenspace Strategy should explicitly address cost-benefit assessments of urban greening with urban water use efficiency programs.

Target 2. State and federal programs are pushing resources toward urban tree planting.

The CARB Scoping plan calls for a 200% increase in the annual investment, relative to business-as-usual for urban tree planting. These resources would be sufficient to drive the tree planting to reach the target. However, we see a major constraint in source material for planting low water, drought tolerant native species. Thus, we identify additional pathways for achieving this target.

- Water efficiency programs work at cross purposes to carbon sequestration objectives.
    - Urban trees gain most of their water from ancillary watering of other urban greenspace. As California incentivizes water conservation, we anticipate that this will increase drought stress and water-limited tree

growth of urban trees. We urge the state to assess this potential impact on urban forest carbon stocks.

- Technical Assistance.
    - Urban tree planting would benefit from a state-sanctioned regional planting list of climate appropriate species for climate smart urban tree planting. Many trees are planted far out of ecological context, and hence do not perform well in their environment. Plant tolerance zones provide a baseline that can be used to create a reference guide for planting. This list should highlight native species when possible, but recognize appropriate non-native tree species for urban environments.
    - Urban tree planting is driven by individual preference of yard trees and limited availability of rootstock for city trees. Nurseries structure inventories to meet these demands. California needs incentives for commercial producers and providers to adjust stock to sell climatically appropriate species for planting.
    - Urban environments are under-stocked with technical advisors that can assist communities in planting climate-appropriate trees. We urge the state work with Community Colleges to increase training of registered foresters for an urban forestry workforce
    - Although CA and the Federal government incentive programs for urban trees have programs to engage underserved communities and direct resources toward these communities, we challenge the state to be proactive to seek out underserved communities and engage them in the difficult conversation about trade-offs of planting trees, water use efficiency and co-benefits of urban greenspace.
    - Non-degree programs at California Community Colleges, such as the UpSkill California (Butte CC) provide innovative opportunities for needed professional training in urban greening.

Target 3. Pathways to reducing continued expansion of developed lands are principally through county planning and external economic drivers (e.g., home insurance availability, construction costs). City and County planning represent the front line of opportunity to plan for reduced urban expansion. In order to better assess the capacity for limiting growth, we identify the following potential pathways.

- The state should create an updatable zoning and planning map that incorporates all county general plans and city zoning plans for permitted existing growth and planned future growth. Matched with county level projections of population growth (California Department of Finance; https://dof.ca.gov/forecasting/demographics/projections/), this information can identify where growth pressure is greatest, where local governments can foster densification and infill, and where open space easements may most effectively limit urban expansion.

- The state should strategically couple 30 x 30 planning, Habitat Conservation Planning, Natural Conservation Community Planning, Mitigation Banking, Regional Advanced Mitigation Planning and Regional Conservation Investment Strategies to open space protection around growing areas to encourage infill growth rather than urban expansion.
- The state should reward cities and counties for planning for stable long-term urban perimeters. The California housing shortage need not be filled through urban expansion. Programs such as the current Regional Housing Needs Allocation program should be used to limit developed land expansion and encourage infill with state programs to increase equity and promote environmental justice. The history of urban development is typified by expansion at the expense of under-served communities. Meeting California's climate goals through promoting densification and infill cannot follow this historical pattern.

Target 4*.* Achieving WUI defensible space standards. The state has guidelines for defensible space in the WUI.

Pathways to achieving this target include:

- Providing resources (i.e., block grants) to achieve defensible communities.
- Increasing technical assistance resources for achieving defensible space
    - Increased emphasis on training of professional vegetation consultants specializing in WUI compliance.
    - Provide technical information on how landowners can achieve defensible space with visually appealing landscaping strategies.

Forests

SECTION 1. Importance of Forests

Forests cover one third—33 million acres—of the state and are responsible for most of its natural carbon sequestration capabilities; they comprise nearly 85% of California's natural carbon stores. Three forest types are considered here: Conifer, Oak, and Riparian. Forests, and specifically conifer forests, are the largest and most expandable of the state's biological carbon sinks, despite fragmentation of their ownership and management histories. Oak woodlands and hardwood forests are slower-growing, and their extent has been significantly reduced and degraded due to conversion for urban and agricultural uses. Riparian forests' extent has been reduced by over 90% and the remaining forests exist in fragments, primarily due to agricultural use and urbanization. Areas dominated by conifer forests are also the primary watersheds of the state, providing the large majority of the state's water supply. Forests occur within a wide range of habitats, from wet and dry meadows to riparian areas, and are therefore extraordinarily important as habitat for myriad species, making them critical for maintaining California's biodiversity as well.

Conifer Forests: California's conifer forests are some of the most biologically productive and diverse in the world as well as some of the longest lived, including, among others, coast redwood, ponderosa pine, and mixed conifer forest types. They are also economically productive, with high value timber and as the basis for jobs in forest management, sustaining rural forest economies. These forests are critical for both carbon and climate benefits, providing irreplaceable adaptation and mitigation services, water supply and quality, and biodiversity. Of the 24.5M acres of conifer forest, roughly half is in public ownership, primarily federal. Many of the most biologically productive forests—those capable of the greatest carbon sequestration increases—are in private ownership. While there are magnificent "reference forests" to be found in parks and some wilderness areas, most of California's forests have been significantly altered by hundreds of years of timber harvest. These forests are relatively young and have been simplified and altered in species composition, age class range, and forest structure as compared to pre-European conditions, and therefore they carry far less carbon than they are capable of accruing. The logging of old growth forests led to emissions of billions of tons of CO_2. Historic fire suppression has also altered these forest landscapes, creating forests with unnatural fuel loads, altered species composition, and greater densities of trees in these previously fire-adapted systems.

Whereas public forests are likely to remain relatively flat in stocks overall, there is a significant opportunity to alter forest management on private conifer forests to increase resilient forest carbon stocks, due to their relatively very young ages (Gray, et al 2020). Further, these younger, more homogenous forests are more susceptible to fire, drought, pests, and the stresses of increased temperatures and major heat events. Of private forests, the industrially owned are generally intensively managed for timber products, and market forces drive harvests at ages well below the natural carbon potential.

These very productive yet relatively young forests are the most expandable carbon sinks of the natural and working land types. Increases in carbon stocks and resilience are feasible by shifting working forests to, on average, older age classes which hold more carbon, and managing for more fire adapted forest conditions including adapting species composition and restoring structural diversity and greater heterogeneity in spacing. While managing to increase fire resilience by, for instance, increased thinning and prescribed fire, leads to intentional CO2 emissions, these emissions are more than offset by the gains from having healthier, faster growing older and resilient forests. Even while decreasing the density of forests by thinning them to more natural, lower densities of trees per acre, managing to restore the more natural forest conditions with larger, older trees would increase total carbon store in those forests by at least 25% (California's Forest Carbon Plan, 2018). Additionally, reducing the intensity and impacts of salvage-based harvests will retain more carbon as well as promote soil health and habitat values in the forest overall.

Gains of at least 150-300 MMT CO2e are feasible in the next 10 years by changing forest management practices in private forests, while keeping them in timber production. The range of benefit will be related to the overall acreage which is involved and the types of management choices for these forests. Further, as less than 5% of the California's private conifer forests are conserved, there is also a significant opportunity to make conservation investments to ensure lasting carbon stores while supporting these changes in forest management. As recommended by the State, priority should be given to source headwaters forests (FRAP, 2017). These changes would also lead to significantly enhanced watershed function and reliability, major gains for biodiversity, reduced threat of extreme fire, and significantly enhance ecosystem function, all of which also promote adaptation within a changing climate. There is thus great opportunity to increase the carbon stocks, climate resilience and other essential benefits of these forests while also addressing a suite of threats to them. Management to achieve these objectives will enhance and sustain employment in forest communities where forest management overall is a key element of rural economies.

Riparian Forests: These are transitional zones between terrestrial and aquatic systems that exhibit characteristics of both systems. They are typically vegetated with lush growths of grasses, forbs, shrubs, and trees that are tolerant of periodic flooding and have sediments that are rich in nutrients and organic matter. Riparian systems look and function differently across the state but possess some common ecological and hydrological characteristics such as fish and wildlife habitat, water storage, flood control, nutrient cycling, water quality protection, recreational and economic benefits, including carbon sequestration – particularly in mature or in restored riparian zones.

The primary literature shows that the establishment of riparian forest will more than triple the baseline, unforested soil carbon stock, and that riparian forests hold on average 68–158 Mg C/ha in biomass at maturity (Dybala et al. 2018). Recognizing the importance of these aspects, the California Riparian Habitat Conservation Program to develop coordinated conservation efforts aimed at protecting and restoring California's riparian ecosystems was created by state legislation in 1991.

Oak Woodlands/Forests: These forests are important to California due to their scenic qualities, wildlife habitats, biodiversity, and cultural values as well as sequestering atmospheric carbon. With some estimates of oak woodland and forests at nearly 13 million acres (over five million hectares) of oak woodlands and mixed oak-conifer forests in California, these oak-related lands have sequestered over 325 million metric tons of carbon in live trees. Another 350 million metric tons of carbon are sequestered in understory vegetation, downed woody material, and soil horizons. Californian valley oak woodlands and savannas can be found in inland valleys and foothills throughout California, providing critical habitat for a diverse range of native plants and vertebrate species; these woodlands have been declining (Whipple et al. 2011). Because of their ecological and cultural significance, California's Valley oak woodlands and savannas are now being protected and restored at many sites within the species' historic range. However, California has an estimated risk of losing 750,000 acres of oak forest and woodland (and subsequently, 33 million tons of sequestered carbon) by the year 2040 (Gaman 2008, Gaman and Firman 2006). Further, modeling efforts have found that climate change may favor oak species, at the expense of conifers (Coffield et al. 2021) providing another incentive to invest in protection of oak forests and the habitats associated with them.

SECTION 2. Recommended actions, strategies, and implementation target(s)

Conifer Forests: These comprise the state’s largest and most expandable biological carbon sink. By 2034, we must expand the amount and resiliency of forest carbon stocks on the most productive privately-owned conifer forest types with working forest conservation easements that improve natural forest structure and function on managed private forestlands. This includes Sierran and Klamath Mixed Conifer, Redwood, Douglas Fir and Ponderosa Pine types. Pair this with restoration investments to, as applicable, reduce stand density and improve structure and composition, and re-introduce managed and controlled fires. Build on state investments to improve fire conditions across the landscape and ownership types.

> **Target**: Increase carbon sequestration by at least 150-250 MMT CO_2e by conserving 1-3 M acres of privately-owned managed conifer forest with working forest conservation easements by 2034, with priority for integration with fuels

management and other forest restoration. These easements should extend the average age of intensively managed forests (exclusive of Water and Lake Protection Zones), reduce salvage intensity, and promote larger older, more well-spaced stands with a natural diversity of species (using the state's Wildlife Habitat Relationships (WHR) classifications). The priority area for focus are those source watersheds supplying most of California's water for agriculture, drinking and environmental water, those most likely to remain most productive under climate change and those most critical for biodiversity protection.

Riparian Forests and related Habitats: There are approximately 350,000 acres of riparian habitat in California, and of this 145,000 are riparian woodlands (Rohde et al. 2021). Riparian forests have been significantly converted to other uses in the state, with a concomitant loss of critical climate adaptation benefits, especially water quality and flow regulation services and providing habitat for myriad species. Protecting mature riparian habitats and restoring altered riparian habitats are two recommended actions to enhance carbon storage in addition to the widely recognized benefits of riparian habitat restoration. Actively planting riparian forest significantly accelerates the biomass carbon accumulation, with initial growth rates (in the first 10 years) more than double those of naturally regenerating riparian forest (Dybala et al. 2018).

Target: Accelerate WCB CA Riparian Habitat Conservation Program to at least 2,000 acres/year target of riparian habitat, prioritizing regionally appropriate projects that focus on functional elements of riparian forest can include co-benefits, particularly for Oak species and for desert or sparsely vegetated ecosystems. Increase riparian restoration by at least double current acreages by 2030.

Oak Woodland and Forest: By 2034 prioritize and protect existing oak forests and replant oak woodland habitat in California to achieve desired densities and age structure targets. Although there is limited potential for large-scale restoration of complete valley-floor ecosystems, extant fragments do remain throughout much of California, particularly in the Sacramento/San Joaquin regions and it is possible that density and distribution patterns similar to the native oak woodlands and savannas could be strategically reintroduced within California valley floors (Whipple et al. 2011) at spatial patterns and range of historical oak densities of 2–30 trees per hectare as well as set minimum densities or age structure targets. Valley oaks could be reintroduced in urban and residential areas as well as in surrounding rangelands at densities comparable to the native oak woodlands and savannas, thereby restoring aspects of ecologically and culturally significant ecosystems, including wildlife habitat and genetic connectivity within the landscape.

Target: Conserve and restore the following oak woodland types and geographies: mixed-Oregon White Oak (*Quercus garryana*) and California black oak (*Q. Kelloggii*) - particularly in northwestern CA; Blue Oak/Blue Oak Pine habitats; replanting or "re-oaking" in Los Angeles/San Diego/Riverside/Orange counties.

Fire Resilience and Forest Restoration: California's forests are all fire-adapted, but fire suppression has drastically altered forest function, composition, structure, and resilience. The current ARB Scoping Plan recommends fire and fuels management on 2.5M acres annually across all forests, shrub, and grasslands. This needs to be more regionally and land type specific, as some systems are more threatened by too much and/or high severity fire (coastal chapparal), while others suffer from too little fire (much of the mixed conifer regions). Efforts need to focus in on fuels management in mixed conifer forest and appropriate oak woodlands (+/- 2 million acres), with the goal of expanding managed fire as the preferred treatment and reducing mechanical approaches. Reforestation should be focused/limited to areas where intense fires have limited natural regeneration.

> **Target:** By 2034, advance fire management to shift at least 75% of landscape fires to beneficial ecological and social outcomes across state. Maintain 2.5M acre fuels management goal, prioritizing up to 2M acres of mixed conifer annually for treatment across public and private lands and with an expansion of efforts in oak woodland areas as feasible. By 2034, have shifted fuels management to be at least 50% via managed and prescribed fire.

SECTION 3. Pathways

Conifer Forests: Allocate minimum of $2B to achieve targeted C gains. An investment of $2B could result in an effective cost (averaged across forest types) of under $35/T at 10 years, dropping to under $20/ton by year 20, and declining thereafter. Utilize a combination of:

- Public funding for the acquisition of working forest conservation easements (WFCES) that is commensurate to that which is spent to achieve carbon reductions in other emissions sectors. This can include new or increased allocations to programs such as the Wildlife Conservation Board, Sierra Nevada Conservancy, Coastal Conservancy, and others, wildfire funding, bonds raised for climate mitigation and adaptation.
- Establish tradeable tax credits for donated easements (or donated portions therof). Tradeable tax credits benefit a broader range of taxpayers, especially lower income populations, than tax credits alone.

Riparian Forests: Increase investment to WCB CA Riparian Habitat Conservation Program (CRHCP) for riparian easement and restoration opportunities. Administrative and funding structures like block grants and/or a small grants program, with technical support starting with the application stage, to ensure funds are accessible to all communities across the state are recommended. Development in riparian habitats should be avoided and riparian habitat restoration or conservation projects should prioritize those which can have co-benefits, particularly for oak species.

Oak Woodlands: A clarification of the CEQA process related to Oak woodlands and carbon sequestration is needed. Serious consideration of county requirements for oak mitigation is highly recommended and with a focus on integrating CA state carbon sequestration standards, prioritizing and incentivizing development that avoids impacts to oak woodlands rather than options to mitigate or replant, where planting or replanting is warranted - establishing monitoring requirements at the city and county level that evaluate mitigation efficiency and determine rates of planting and re-planting rates that avoid losses and promote expansion of oak habitat, and the development of incentives for voluntary oak woodland conservation. Conservation options such as fee or conservation easement purchases should be implemented and especially for Blue Oak types. Expand use of prescribed burns, as appropriate, to improve restoration of understory communities and promote longevity of oak stands.

Fire Resilience: By 2025, scale up, and speed up implementation of, prescribed fire operations at CAL FIRE to enable the agency to implement managed/prescribed fire at the hundreds of thousands of acres level annually by utilizing the same systems and authorizations for prescribed and managed fire as for fire suppression. By 2026, have a state-developed template permit system for fuels management on smaller privately owned forests (under 500 acres in ownership) that streamlines family forest fuels management, with priority for watershed implementation. Overall, expand engagement with Tribes for use of Traditional Ecological/Indigenous Knowledge in fire management, with a strong concentration on oak woodlands and mountain meadow mosaics within conifer and mixed conifer systems.

Grasslands

SECTION 1. Scope and importance

Grasslands are defined as lands that have <10% tree canopy cover and are dominated by grasses or other herbaceous vegetation. Grasslands in California experience considerable diversity in geology, soil type, and climate, with distinctions often made between coastal grasslands, valley grasslands, and cold and warm desert grasslands. California grasslands dominate the Valley floor and extend to oak woodland (savannas) up to elevation of about 1,500 ft. They make up 9-10% of California's land area totaling approximately 10-14M acres storing about 330 MMT of carbon (C) (Stromberg et al. [eds] 2007; Eviner 2016; 2022 Scoping Plan). Since the 1600's, introduction of exotic annual grasses by Spanish colonists and overgrazing have drastically altered plant and animal biodiversity. Prior to colonization, some researchers suggest the area was dominated by perennial bunchgrasses such as purple needlegrass (*Nassella pulchra*), the state grass of California. However, other researchers hypothesize that inland grasslands were historically dominated by forbs (Wester 1981; Schiffman 2000). Today, more than 99% of native California grasslands have been converted to development and agriculture. California grasslands can be a source or sink of C depending on the environment and its management, with oak woodlands serving as more reliable sinks (Ma et al. 2007). Tree removal in the 1960's was a standard practice to increase forage production leading to significant loss of soil C. Oak trees and foothill pines create Islands of fertility with increased soil C, about 3x higher than open grassland (Carey et al. 2020; Dahlgren et al. 2003). The majority of the carbon is belowground, which has implications for future stability in a world marked with increasing intensity of wildfires (Dass et al. 2018). In fact, the 2022 CARB Scoping Plan predicts that, unlike some of the other ecosystems, grassland C can be maintained or improved with management even in the face of stressors such as drought. Reintroduction of trees and reducing conversion of grasslands represent management opportunities to increase C stocks. However, grasslands occupy diverse ecological site conditions and soils resulting in varying biogeochemistry and climate conditions that affect the ability to store soil C. Recommended management strategies will differ by grassland type and region and will influence recommendations management actions related to each Target.

Nearly 90% of annual grasslands in California are privately owned (Huntsinger et al. 2007). The primary land-management activity on these grasslands is livestock grazing, mainly of cattle. Grazing occurs on both private and public lands in California. Many ranchers love ranching for the lifestyle, working with animals, and being in nature, but it is often difficult for ranching to be the sole income. Often more than one income is required to support a ranching family. While we touch on other land-ownership scenarios, our recommendations focus heavily on supporting ranchers so they can protect and restore grassland C.

SECTION 2. Recommended actions, strategies, and implementation target(s)

We recommend two targets that focus on protecting and rebuilding soil carbon:

Target 1. Reduce the annual conversion rate of grasslands by 75%.

Target 2. Invest at least $50M annually to support implementation of practices that help promote soil health principles and protect/rebuild carbon on grasslands.

To achieve these targets, it will be imperative to prioritize regionalized approaches that are intermittently re-evaluated. Equally imperative is re-evaluating the targets themselves over time to ensure they are creating the desired mitigation results with minimal trade-offs.

SECTION 3. Pathways to reach the implementation target(s)

Target 1. Reduce the annual conversion rate of grasslands by 75%.

Pathways to achieve Target 1 should focus on supporting financial stability of ranching operations, given a considerable amount of grassland in California is grazed. Financial stability of ranchers helps ranchers maintain their ranch and reduces the need to sell land and/or convert management to more intensive agriculture or more intensive human development. However, many of the pathways can also support non-grazed grasslands as well, and those options are also important to consider. Pathways to help improve financial stability and reduce annual conversion include (Cameron et al. 2014):

- Conservation and agricultural easements
- Legislation that reduces property taxes through voluntary programs such as the Williamson Act
- Publicly funded voluntary conservation incentive programs akin to the USDA Grassland Reserve Program
- Land acquisition by state agencies or land trusts in areas under high threat of conversion
- Expansion of grazing on state lands (where ecologically beneficial) to help increase land access for lease options

Target 2. Invest at least $50M annually to support implementation of practices that help promote soil health principles and protect/rebuild carbon on grasslands.

Pathways to achieve Target 2 should focus on bolstering existing programs that focus on grant-making for and incentivizing the maintenance of existing carbon stocks and implement carbon sequestration practices. We also encourage pathways that leverage concurrent investments to restore wildlife habitat and water resources, since many practices provide joint benefits for water, wildlife, and the climate. Funds should include support for planning, supplies, infrastructure, technical assistance, and monitoring associated with implementation. Additionally, practices should be incentivized based on the latest science and should be regionally appropriate. At this time, we recommend the state review and consider the following practices: perennial plant establishment (via riparian restoration, re-establishment of native oak trees, windbreak and hedgerow plantings, and promotion of perennial grasses), soil amendments (e.g., compost addition), prescribed grazing (to minimize overgrazing and mitigate severe wildfires), and promotion of grassland cover and diversity (via range seeding or prescribed grazing).

Pathways to support investment in practice implementation include:

- Incentive-based voluntary stewardship programs such as CDFA's Healthy Soils Program
- Traditional grantmaking through existing entities such as the California Department of Fish and Wildlife and the Wildlife Conservation Board
- Block grants awarded to conservation organizations and technical assistance providers for regranting and other implementation support. This includes Resource Conservation Districts and non-profit organizations.

Supporting the development of regional, climate-smart markets will help to drive participation in these voluntary programs. Another critical enabling mechanism will be to fund research for an improved understanding of practice impact that can minimize investment risk over time. Funding research on emerging technology and approaches that can help with practice implementation (including virtual fencing, inoculant-supported restoration of oaks, and compost procurement and application rates) will also be helpful, as will ensuring sufficient payment rates and levels of technical assistance are available for all practices and projects.

Improving or developing decision-support tools and frameworks that help spatially prioritize investments will also be critical to maximize benefits and minimize trade-offs. There are many approaches that could be used but include bolstering NRCS Ecological Site Descriptions for grasslands statewide, developing high-resolution maps of soil carbon stocks that reveal opportunities for large gains via protection and restoration, and producing robust "soil health curves" for carbon by region and soil type.

Shrublands

SECTION 1. Outline scope and importance of land sector

Shrublands occupy up to 32.9 million acres in California (CNRA 2022), as chaparral, coastal scrub, sagebrush steppe, and Mojave desert scrub (Barbour et al. 2007, Mooney and Zavaleta 2016). Shrub components are interwoven with other ecosystem types and can be transitional following forest fire. These varied shrublands have different characteristics, threats, and management needs. Threats to coastal sage scrub and chaparral include invasive species, high fire return intervals limiting recovery post-fire, and urban development (Cleland et al. 2016, Parker et al. 2016). A major goal in these two shrub ecosystems is to maintain existing stands. On the other hand, while urban development is a threat to northern coastal scrub, in some places northern coastal scrub should be controlled to maintain coastal prairie grasslands (Ford and Hayes 2007), which has been identified as a 'sensitive plant community' by the California Department of Fish and Game and California Coastal Conservancy (Ford and Hayes 2007). In areas with coastal prairie, maintaining disturbance to prevent type conversion to shrubland is important. Similarly, following fire in forested sites, shrubs can rapidly establish and maintain dominance for many years, depending on fire severity, site conditions, and tree legacies (Lavaux et al. 2016). While shrubs have historically been part of heterogeneous and diverse fire-adapted forest landscapes, it is the processes that produce a heterogeneous landscape that require conservation, not individual shrub patches.

In this document we focus our recommendations on coastal sage scrub and chaparral. Chaparral is the most abundant vegetation type in the state (Parker et al. 2016). In the future, the state should incorporate recommendations for all shrubland types.

SECTION 2. Recommended actions, strategies, and implementation target(s)

Shrubland ecosystems are included in the 2022 Scoping Plan target to treat 2-2.5 M acres of forests, shrublands and grasslands per year to increase wildfire resilience, but many treatment types identified in the Scoping Plan are not appropriate for shrublands. Also, it is likely that treatments in shrublands will be much more limited in acreage than those in forests due to both opportunity and costs of treatment. Climate mitigation and resilience in shrublands should prioritize retaining and increasing carbon stored in biomass and soil and increasing human community resilience to wildfire by reducing fire frequency and emphasizing smart growth. Our targets and pathways are specifically related to chaparral and coastal sage scrub communities.

1. *Address fire threats to shrubland ecosystems and adjacent human communities through developing and expanding fire ignition prevention programs that prioritize the largest sources of ignitions, as well as through home and community hardening.* Education and funding should be provided (especially for

low-income people in vulnerable communities) to retrofit homes/structures to make them more fire safe and to conduct defensible space training.

In southern California in particular, fire return interval departure maps reveal that fire return intervals are too short. Humans are the number one cause of fires in chaparral and coastal sage scrub ecosystems, increasing fire frequency, which reduces shrubland carbon stocks. Therefore, to increase carbon stored in biomass and soil in these shrubland types, efforts should seek to extend the fire return interval, reducing the number of fires on the landscape. Fire prevention efforts should *avoid* any treatments that increase flammability such as thinning and mastication, which promote grass invasion into shrublands.

2. *Pursue conservation and restoration of a minimum of 30x30 for each declining shrubland ecosystem type, based on the best available climate-change science, and pursue smart growth that minimizes development impacts to shrublands.*

   Shrubland ecosystems store carbon above and belowground and harbor endemic species. Protecting shrubland habitats from development limits carbon loss from these ecosystems and can enable climate resilience for endemic species. Important habitats for conservation include chaparral, serpentine chaparral, coastal sage scrub, and alkali sink scrub in non-forest regions across California. Conservation of 30% of these habitats in an undeveloped condition is a floor; for coastal sage scrub, which has just 1% remaining, conservation should target all of the undeveloped area. Multi-benefit conservation should be sought and, where it is effective and beneficial, restoration pursued. Restoration includes improved management of protected areas to address threats from invasive species, fire, and other pressures.

SECTION 3. Pathways to reach the implementation target(s)

Pathway for Target 1: A major concern for shrubland management has been addressing fire risk to human communities embedded within or adjacent to shrubland habitats. Human communities within shrubland-dominated wildland-urban interface (WUI) zones require a community and regional scale approach to fire risk mitigation that includes multiple components (Moritz et al. 2022). This may involve novel strategies such as creation of well-maintained buffering land uses, reduction of flammable areas along key ignition pathways such as roadsides or powerline corridors, along with improvements in fire fighting and public safety infrastructure. Fuels treatments, such as thinning, mastication, and prescribed fire, that promote non-native grass establishment in shrublands can increase fire risk and should be avoided unless there is a specific cultural interest (Anderson and Keeley 2018, Marks-Block et al. 2021). Instead, ignition prevention should be a priority in shrubland WUI areas. Fire Wise Communities and Community Wildfire Protection Plans (CWPPs) can be successful avenues for education and change around home hardening and defensible space. Fire Safe Councils, Prescribed Burn Associations, Resource Conservation Districts, among others may be able to develop and implement ignition prevention programs based on input from experts in the field. Funding and technical assistance for regional planning and funding for low-income people in vulnerable areas to retrofit homes/structures is needed.

Pathway for Target 2: California's shrublands harbor carbon above and below ground, and are home to diverse, often endemic, plant and animal species. Pathways to 30x30 identifies regionally specific shrubland habitats for conservation, including chaparral, serpentine chaparral, coastal sage scrub, and alkali sink scrub, each requiring conservation targets. A priority is to develop a conservation strategy for declining shrublands and shrub species that meets or exceeds 30% by 2030. Regional conservation planning enabled by federal Habitat Conservation Plans and state Natural Communities Conservation Planning may provide a template or framework in some communities for conservation efforts. Conservation easements and outright purchase could both be used. There are few data on shrubland carbon stocks and residence times in these varied ecosystems (Gonzalez et al. 2015, Bohlman et al. 2018), and just a few projections for effects of climate change, which primarily focus on the large shrubland area in Southern California (Malanson 1991, Tauge et al. 2009, Underwood et al. 2019). Therefore conservation and restoration efforts should engage scientists to learn how shrubland species and ecosystems are expected to change, and prioritize conservation and restoration based on the best available science informed by climate change projections. There is a need to identify climate-change refugia for at-risk shrubland species. Expert elicitation and listening sessions with scientists, tribes, and restoration and conservation practitioners, to target carbon sequestration and biodiversity objectives in major shrubland regions and types throughout the state, should be used to determine specific targets and specific acreage for each shrubland type.

Beyond conservation and restoration, AB 1445 now requires counties and cities to consider wildfire risk and climate change in planning new housing development in long term general plans. Planners should consider shrubland fire regimes and risks, and how these may change with climate change in siting new development. Expanding beyond parcel-scale hazard reduction to larger scales is critical for both reducing shrubland fire ignitions by people, which is the largest source of ignitions, and for reducing fire risk to communities. Expanded technical assistance for smart growth planning efforts is needed to expand them to all areas of the state where shrublands are a dominant part of the landscape.

Wetlands

SECTION 1. Scope and Importance of Wetlands

Wetland ecosystems have aquatic and terrestrial characteristics, and they range from seagrasses, tidal and non-tidal wetlands to riparian wetlands, vernal pools and mountain meadows. Though small in area, wetlands are carbon (C) sinks, can be sources of greenhouse gases (GHG), and provide many additional ecosystem benefits. The C density of most wetlands soils is higher than for any other land classification. Seaweeds also may act as significant carbon sinks, though research on this topic is still emerging (Pessarrodona et al. 2023).

In addition to GHG benefits, wetlands and seaweed habitats provide valuable ecosystem functions including habitat for birds, fish, and other wildlife. Wetlands provide many important hydrological benefits, including flood protection, groundwater recharge, shoreline protection and erosion reduction. They also play key roles in nutrient cycling and the fate of contaminants.

Loss of wetlands is primarily attributed to agricultural conversion and development, with California having the highest rate of wetland loss (~90%) in the US. Wetland drainage leads to significant C and GHG emissions, as stored soil C is oxidized, along with high rates of local subsidence (Deverel et al. 2020). Climate change poses a significant threat to wetlands, with shifts in precipitation and hydrology outcomes. Wetlands along the coast also face flooding from potential sea-level rise. Some seaweed habitats have also declined across the state, facing numerous climate change-induced threats (e.g., McPherson et al. 2021).

Management and restoration provide many opportunities to restore C and reduce GHG, and improved data availability and model advancements make tracking these opportunities more feasible than in the past. Conserving and restoring existing wetlands and seaweed ecosystems is critical to maximize their environmental, cultural, and social benefits.

SECTION 2. Recommended Actions, Strategies, and Implementation Targets

Given that only Delta wetlands were included in the 2022 Scoping Plan, an overarching goal for the State's wetlands is to incorporate emissions projections for existing and restored tidal wetlands and eelgrass into the next Scoping Plan. These systems offer immediate opportunities to improve emissions projections because of the amount of available research and modeling efforts, and because of negligible methane emissions from saline ecosystems (Poffenbarger et al. 2011). In recommendation #3, we highlight data gaps that should be addressed for other wetland ecosystems and seaweeds so that they can be incorporated into subsequent Scoping Plans.

1. **Set restoration targets for freshwater wetlands in the Delta, saline and brackish tidal wetlands, and eelgrass meadows:**

    - The current target for the Delta and Suisun Marsh should be increased to 32,500 acres of tidal habitat restoration, and 50,000 acres of managed wetlands and rice cultivation by 2045.

    - Target the restoration of 20,000 acres of tidal wetlands in San Francisco Bay by 2045. Although specific acreage targets are not immediately available for the rest of the state, we recommend restoration to increase tidal wetlands by 20% in 2045 across coastal California, with the need for more focused regional plans to develop specific acreage targets for tidal wetlands in each region and update targets based on future regional plans.

    - Target the restoration of 300 acres of eelgrass in San Francisco Bay by 2030 and 3,000 acres by 2038. Similar acreage targets for 2038 and 2045 should be developed by 2030 for other regions, once progress has been made on recommendation #3; regions holding a significant proportion of the State's eelgrass should be prioritized.

2. **Prioritize conservation and restoration approaches that preserve and maximize existing carbon stocks and other wetlands ecosystem benefits for nature and people:**

    - Conservation of least-disturbed wetlands of all types across the state should be a priority given that these systems have the potential to greatly reduce carbon emission and/or sustain on-going carbon sequestration, while ensuring persistence of other, difficult-to-regain ecosystem benefits.

    - Use restoration approaches that maximize carbon sequestration benefits (bearing in mind social risks and other ecosystem benefits) such as tidal reconnection, rewetting, and beneficial use of dredge sediment. Projects should also consider approaches that lead to diverse wetland and estuarine landscapes (e.g., restoration of both seagrass and neighboring tidal wetlands).

    - Use restoration approaches that address long-term resilience to future anthropogenic and climate stressors (e.g., targeting conservation of areas that will provide migration space for sea-level rise impacts to coastal ecosystems).

3. **Complete detailed, state-wide mapping of wetland and seaweed ecosystems at least once every five years, with an initial survey completed by 2030. Additional priority data gaps across multiple ecosystems include:**

- **Delta**
  - Continue to improve emissions estimates for non-tidal and tidal wetlands in the Delta and Suisun Bay, including rice fields, managed perennial and seasonal freshwater wetlands, and tidal wetlands.
- **Brackish and salt marshes**
  - Expand tidal wetland data acquisition and modeling to coastal systems beyond the San Francisco Estuary. Most blue carbon research and modeling has been done in the San Francisco Bay-Delta, with less data from the southern California coast and even larger knowledge gaps for central and north coast wetlands.
  - Improve integrated modeling of sequestration and emissions for tidal wetlands. Multiple models exist for carbon sequestration in tidal wetlands, but they are not linked to emissions. Integrating these models with spatial datasets will improve estimates of their potential in statewide carbon reduction.
- **Seagrass**
  - Support collection of California eelgrass carbon sequestration and emissions data, which are sparse but increasing, and their incorporation into models to evaluate habitat-wide carbon sequestration.
  - Support investment and research in eelgrass restoration (in implementation and development of habitat suitability models), which will need to expand to meet acreage targets.
- **Seaweed**
  - Determine the carbon-sequestration potential of California kelp forests and nearshore algal beds. The long-term C sequestration potential of macroalgae is unclear given it is presumed to largely occur far away from existing forests, in deep ocean sediments and as recalcitrant carbon in aqueous pools. Science to evaluate this potential will inform the role of seaweeds in California's climate goals.
  - Improve understanding of kelp forest restoration approaches. Given that efforts to restore California kelp forests following extreme loss are nascent, many gaps remain on the best approach, scalability and how to ensure efforts are successful and meet community needs. Improved mapping can also facilitate informed restoration and management decisions.
- **Mountain meadows**
  - Improve understanding of spatial variability and drivers of carbon dynamics in mountain meadows. More information is needed on the

extent of these important regional carbon sinks on the impacts of forest management practices.
  - Improve understanding of how mountain meadows interact with fire behavior and fire impacts, affecting carbon storage both in the wetlands and in the forest.
  - Work with state, federal and regional stakeholders to develop regional plans to restore mountain meadows.

SECTION 3. Pathways to Reach the Implementation Targets

Overall Mapping of Wetlands and Seaweeds

Inland wetlands are innate landscape features acting as water sources, regulating water quality and providing unique wildlife habitats. Coastal wetlands provide shoreline stability and critical wildlife and fisheries habitat. Wetlands also have significant cultural value for both indigenous peoples and others. Yet there is a dearth of information of their extent and influence on the landscape. Mapping the extent of wetlands more accurately is an essential component to improve future emissions projections. This information is also necessary to assess the state of degradation, planning for restoration and implementation of restorative efforts to reclaim these important features of the landscape. Based on recent efforts for intensive mapping of tidal wetlands in San Francisco Bay, approximately $10 million would be need to provide mapping of tidal wetlands and mountain meadows across the state every five years from now until 2045, a frequency that will provide effective information for conservation and restoration targets. Additional funds are needed for mapping of eelgrass and seaweeds.

Eelgrass

Previous iterations of CARB's scoping plans do not include eelgrass acreage targets. Other existing targets and data can inform target development, but will require support for development and implementation. A habitat suitability model developed for San Francisco (SF) Bay identifies a maximum potential eelgrass habitat area of 23,440 acres, with only about 3,000 acres of eelgrass currently present (Boyer and Wyllie-Echeverria 2010). Previous goals in Vaughn et al. (2022) state goals to restore 3,000 to 6,000 more acres of eelgrass in SF Bay, while OPC (2020) sets a statewide goal of 1,000 acres by 2025. However, past efforts to restore SF Bay eelgrass accomplished roughly 100 acres in a decade, given technical challenges, personnel requirements, and investment. Thus, the acreage targets set herein are a reflection of potential restoration area balanced with feasibility. Meeting acreage targets in the thousands of acres will require advances in restoration, with financial support and new supporting science. Additionally, spatial data, suitability models, and basic monitoring do not exist everywhere, making verifiable regional or statewide targets difficult to set. Eelgrass mapping is challenging given they are not often visible from satellite platforms.

Technological improvements (e.g., UAVs, side-scan sonar) in mapping making the recommended one-time comprehensive monitoring and 5-year site specific monitoring more feasible, ideally as a part of a broader, statewide long-term monitoring plan. The California Eelgrass Mitigation Policy and other state guidance documents can guide standard monitoring practices, and support from State and Federal agencies and partners such as the California Ocean Protection Council, the Southern California Coastal Water Research Project and NOAA can facilitate development and implementation of such efforts (NMFS 2014). Lastly, even with sufficient monitoring and scalable restoration, additional scientific work is required to determine the impact restoration outcomes have on carbon reduction. For example, targeted investments could facilitate development of models tailored to state needs and filling the knowledge gaps identified above.

Seaweed

Seaweeds are unique in their carbon-reduction role via export below the ocean mixed layer and in deep ocean sediments (Krause-Jensen Duarte 2016). There is a dearth of information on seaweed limiting carbon management activities, meriting funding to address the gaps identified above. Kelp forest restoration is also poorly understood, with a need to ID appropriate restoration approaches, particularly given the high spatiotemporal variability of kelps (Cavanaugh et al. 2019; Rogers-Bennet and Catton 2019). Similar to seagrass, improvements in remote sensing makes monitoring these habitats more feasible, but with high species-specific variation. Programs to regularly monitor these habitats will be essential (See OPC 2020).

Tidal and Non-Tidal Wetlands

Within the Delta, efforts are underway to restore wetland and introduce rice for subsidence-reversal, with multiple projects underway or in planning with funding from the Sacramento-San Joaquin Delta Conservancy. Additional acreage could be achieved through this program with additional funding. The Delta Plan targets 30,000 acreage for subsidence reversal by 2030, and substantial additional opportunities could be leveraged by 2045 (Delta Plan, Chapter 4, Amended 2022: https://deltacouncil.ca.gov/delta-plan/). In addition to large benefits related to reduced greenhouse gas emissions with reflooding of drained land (Holmquist et al. 2023), subsidence reversal in these areas provides added benefits in reducing stress on levees and seepage (Deverel et al. 2020; Windham-Myers et al. 2023). Similarly the Delta Plan has set targets for tidal and floodplain restoration in the Delta and Suisun Marsh that exceed the Scoping Plan targets, with 32,500 acres of tidal wetlands, as well as even greater acreages of other wetland types (e.g., seasonal and riparian wetlands) in the region that should be incorporated into future emissions projections as improved data become available for these wetlands (see Appendix E, Performance Measure 4.16 for details: https://deltacouncil.ca.gov/delta-plan/).

Large-scale efforts are underway for the restoration of tidal wetlands in SF Bay, with the establishment of the SF Bay Restoration Authority (https://www.sfbayrestore.org/)

and multiple large-scale projects, including the South Bay Salt Pond Restoration Project (https://www.southbayrestoration.org/). The Goals Project (1999, 2015) set long-term targets of 60,000 acres of tidal wetland restoration for SF Bay but did not establish a temporal time frame for these targets. Vaughn et al. (2022) set targets between 17,000 and 27,000 acres. While most of these efforts have focused on habitat, flood protection, water quality, and public access, tidal wetlands do provide high rates of carbon sequestration (Drexler et al. 2009; Callaway et al. 2012). Recent research has focused on evaluating emissions and efforts are underway to integrate past models of soil carbon with emissions. For example, the MEM-PEPRMT model is currently being developed to incorporate these components, and modeling efforts could be advanced through increased support for data on marsh elevation changes, biomass, and tidal data (Mack et al. 2023). The Southern California Wetlands Recovery Project (2018) set regional goals for preservation, restoration, and future migration of coastal wetlands in southern California with a future sea-level rise of 24 inches. While these goals are not directly applicable to current conditions, they provide a basis for regional targets of acreage, sequestration, and emissions. The north and central coastal areas of the state lack regional goals; they would benefit from regional evaluations of restoration opportunities that could guide sequestration and emission targets.

Mountain Meadows

Mountain meadows are found on the slopes of Sierra Nevada, Cascade and Coast range mountains. Their riparian and meadow soils contribute disproportionately to water retention and quality, forage production, and wildlife habitat. Human activity and grazing have led to the degraded state of these wetlands. The condition and spatial extent of these wetlands needs to be better characterized with up to one half or more having lost 50% of their soil C (Norton et al. 2011). These wetlands should receive priority to restore soil C levels, water quantity and quality and other ecosystem benefits which will require funding to address the gaps identified above. In the Sierra Nevada's, there are more than 18,000 meadows comprising 280,000 acres, about a third located in National Forests. The Sierra Meadows Partnership (https://www.sierrameadows.org) is an example of a public/private organization with a mission to restore wetlands. They have completed a Sierra Meadow Strategy focused on restoring 30,000 acres by 2030. Ideally, 100% of meadows in all mountainous areas should be restored or in a state of restoration by 2050 to increase water security for Californians and habitat for wildlife. Mountain meadow inventories need updating, especially for the Cascade and Coast ranges. Meadow restoration is vital and can contribute significantly to regional targets of carbon, sequestration, and other climate change abatement efforts (Reed et al. 2021, 2022). Restoration of Cascade and Coast Ranges lack regional goals and would benefit from regional evaluations of restoration opportunities that have been identified in the Sierras. Funding for the California Departments of Wildlife and Conservation Board and Fish and Wildlife at $25 million annually would provide wrap-around technical support for meadow restoration and cost sharing programs with regional entities such as the Sierra Meadows Partnership. It is recommended to seek additional cost sharing opportunities with organizations such as USDA Forest Service, Bureau of Land

Management, counties, environmental organizations and the National Fish and Wildlife Foundation for long-term restoration projects.

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