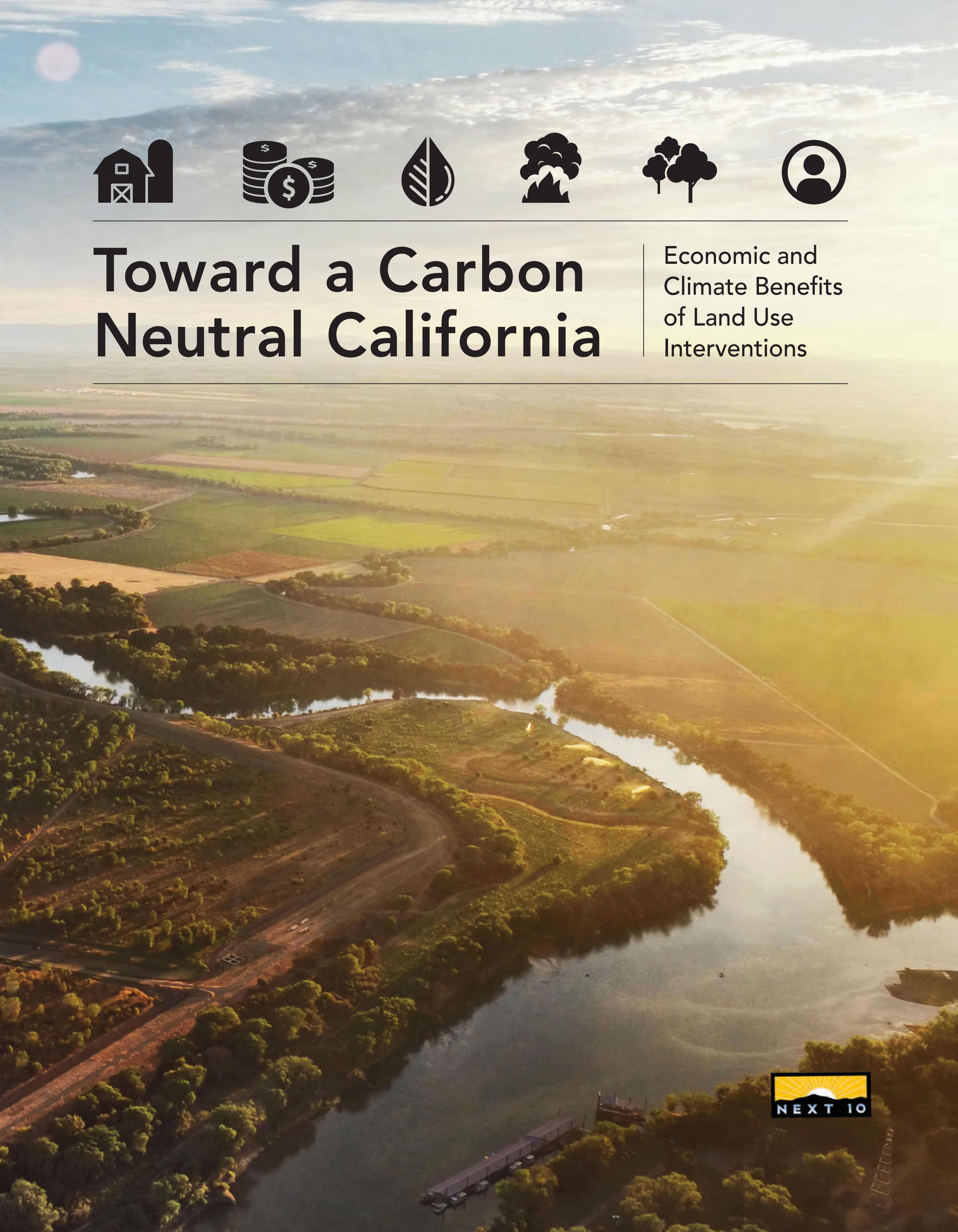

Toward a Carbon Neutral California

Economic and
Climate Benefits
of Land Use
Interventions

NEXT 10

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Executive Summary

BUILDING on its leadership to address climate change, the state of California increasingly recognizes the critical role that management of natural and agricultural ecosystems can play in helping to meet climate goals. Through the implementation of conservation, restoration, and management practices and policies, both public and private entities can reduce emissions and increase the sequestration capacity of the land. Collectively, these practices and policies are called “natural climate solutions” and have been shown to materially contribute at statewide and global scales.[1,2]

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California has already invested nearly $1 billion from its Greenhouse Gas Reduction Fund (GGRF) in land-based strategies to reduce emissions, building momentum to meet the state's 2030 greenhouse gas (GHG) reduction goal with an enhanced role for land-based climate strategies. In September 2018, Governor Brown released an Executive Order (B-55-18) setting a goal to make the state climate neutral, if not carbon negative, by 2045. This represents a significant opportunity to advance "negative emissions" strategies that can pull CO_2 out of the atmosphere, such as land conservation, restoration, and management. Indeed, the role of natural climate solutions becomes even more important when one considers that many of the other strategies suggested or piloted (e.g. direct air capture) to create "negative emissions" thus far rely on technologies that do not yet exist at scalable, cost-effective levels. Therefore, it's imperative the state invest heavily in this proven sector, while also exploring other opportunities. To help guide this investment, the state should create a roadmap to determine how land-based strategies might be implemented to help meet these goals. This need is sharpened by a growing risk that GHG emissions from wildfire will increase in the future due to trends in climate change and management history.

This study seeks to inform the state's GHG reduction goal for natural and working lands by providing an initial estimate of the climate mitigation benefits and costs of eight representative land management interventions under two alternative climate futures, using the LUCAS model. Climate mitigation from these interventions, or "net" emissions reductions, come from either "avoided emissions" and increased sequestration where atmospheric GHGs are stored in vegetation and soils (Table 1). These interventions or activities were selected based on their GHG reduction potential, their ability to be modeled using the LUCAS model, and because of the co-benefits they provide. They are also feasible to implement at broad scales given current technology. The effect on land-based carbon storage from these interventions is compared to a "control" run for each climate future in which interventions are not implemented. This study also quantifies the costs of implementing these interventions and provides an initial estimate of select economic benefits. Direct and implicit or opportunity costs of implementing interventions are presented to provide decision-makers with an initial estimate of the range of potential costs to integrate these activities into state climate policies.

To estimate the economic impacts associated with each intervention, one-time direct implementation expenditures and opportunity costs (foregone economic benefits due to an intervention) were calculated. All interventions except for **avoided conversion** and **changes to forest management** had direct costs. A subset of interventions had opportunity costs consisting of foregone returns to agricultural, forestry, or urbanization, including: **avoided conversion, changes to forest management, riparian restoration, and woodland restoration.**

To further capture the economic impacts of these interventions, the value of select opportunity benefits created by each intervention relative to the control scenario were calculated in addition to implementation and opportunity costs. First, the social cost of carbon (SCC) was used to estimate the economic benefit of avoided emissions as most interventions generate net emissions reductions relative to the control by 2050. Additionally, for two interventions—**avoided conversion** and **riparian restoration**— the social cost of nitrogen (SCN) was used to value the economic benefit of avoided nitrous oxide (a potent greenhouse gas) emissions and water quality impairment caused by reduced application of nitrogen fertilizer to agricultural fields. The avoided cost of flood damages associated with reduced urbanization in floodplains was estimated. Finally, the avoided cost of suppressing high severity wildfires was also calculated for the **reduced wildfire severity** intervention. It should be noted that this study does not attempt to provide economic analysis for many of the co-benefits resulting from the scenarios, nor does it calculate indirect economic benefits. It is likely that several scenarios would be even more cost-effective were these benefits considered, and further research could help quantify these benefits.

TABLE 1 Intervention Scenario Models and Land Cover Classes

MANAGEMENT TYPE	LAND COVER CLASS AFFECTED					
Forestry	**F**	**AA**	**AP**	**G**	**S**	**D**
1 **Reduced Wildfire Severity**[†] A variety of forest management practices are used to reduce fuel loading in forests.	●					
2 **Post-Wildfire Reforestation** Active replanting of trees in areas that burned under high severity fire.	●				●	
3 **Changes to Forest Management** Shifts in current forest management practices to increase carbon stocks and reduce harvest volumes.	●					
Restoration						
4 **Woodland Restoration** Planting native hardwoods in areas where they have been removed or lost due to land use change.				●		
5 **Riparian Restoration** Establishing forest cover along the banks of streams and rivers in agricultural and grassland regions.		●	●	●		
Agriculture						
6 **Agroforestry** The establishment of trees along agricultural field boundaries to act as a windbreak.		●	●			
7 **Cover Cropping** A rotation of non-cash crops when an agricultural field would normally lay bare to increase soil carbon.		●				
Conservation						
8 **Avoided Conversion** Reduced rates of land conversion due to urban or agricultural land use.	●	●	●	●	●	●

[†] assuming 10% & 30% high-severity fire

Note: F: forest, AA: agriculture-annual, AP: agriculture-perennial, G: grassland, S: shrubland, D: developed. Details and model assumptions are described in the Intervention Results section.

Key Findings

Despite naturally declining carbon stocks under both climate futures, the interventions collectively achieve emissions reductions: In total, the interventions analyzed resulted in net positive climate benefits by 2030, 2050, and 2100 despite a downward trend in carbon stocks (the amount of carbon stored in soils, dead organic matter, and vegetation) under the control run of each climate model. The largest reductions in net emissions resulted from avoided conversion of natural and agricultural land and changes to forest management on private timberland.

The aggregate emissions reductions from these interventions could help the state meet its 2050 climate targets and become carbon neutral by 2045: Their collective emissions reductions range from five to seven percent percent of the reductions the state needs to make in order to meet its GHG reduction goal for 2050. In both climate models, there is a reduction of over 260 million metric tons of CO_2 cumulatively (under 30% high severity fire scenario) by 2050. This is 2.5 times greater than the reductions expected to be produced by the residential and commercial sectors combined and 80 percent of both industrial and agricultural emissions reduction modeled to meet California's 2050 climate target. These interventions can also support efforts to become carbon neutral by 2045.

The economic benefits are significant, even with a limited scope: The cumulative economic benefits of these reductions are as high as $14.9 to $17.2 billion by 2050, and include the benefits of not emitting CO_2 or nitrogen-based greenhouse gases or pollutants, as well as the avoided costs of damages due to flooding urban areas and suppressing high severity wildfires. This includes a quantification of only a few of the environmental benefits associated with conservation or increased adaptation to climate impacts associated with the interventions modeled— the estimates could be significantly higher if they accounted for other direct and indirect economic benefits.

Economic benefits help balance opportunity cost: The cost of implementing these activities is driven by their opportunity costs. The opportunity cost of an activity is the economically-productive land use the activity prevents. Opportunity cost includes the present value of forgone net returns from residential and agricultural land use through perpetuity and the present value of forgone net returns from managed forest land use through 2050. Direct implementation and opportunity costs range from $32.6 to $35 billion for the "average" and "hot-dry" climate futures respectively from 2020 to 2050. This equals about $1.2 billion (2020-2050) a year for the high estimate. So, for every dollar spent on implementation and incurred as an opportunity cost, $0.49 is paid back in terms of benefits under the "hot-dry" and $0.46 under the "average" model.

Yet, there are many benefits that are not included in this assessment that would certainly make the cost-effectiveness of these interventions even more favorable, including the increased amenity, recreation, and public health benefits of maintaining natural land near cities, the benefits of more compact growth patterns in terms of shorter commute times, less traffic, and associated social and environmental benefits. This study did not account for the indirect GHG emissions associated with urbanization and increases in cultivated agriculture, but by preventing those emissions, the avoided conversion intervention also provides indirect climate benefits.

260 million

metric tons of CO_2 captured by these interventions

5-7 percent

of the emissions reductions the state needs to meet its 2050 climate goal

For the benefits provided, these interventions are relatively cost-effective: When considering the price per ton of CO_2 emissions reductions compared to other sectors' activities, the majority of the activities for which there were net reductions by 2050 are relatively cost-competitive. For example, avoided conversion is the second most expensive intervention besides riparian restoration with a cost per ton of CO_2 reduced equal to $130 from 2020-2050 using discounted rates. Yet, this makes it cheaper than all but one of the eight programs administered by California Air Resources Board as part of the California Climate Investments Programs in 2017.[3]

The variable future risk of wildfire greatly impacts emissions savings potential, but conservative estimates show a net reduction by the end of century: Reduction of high-severity wildfire events by implementing thinning and prescribed burning projects reduces overall areas burned under high severity by over 1.5 million acres by the end of the century. Because this intervention removes carbon from the forest as part of the restoration action, it results in emissions until after 2060. After this point, both models under the 30 percent fire severity scenario start to result in net emissions reduction through the avoidance of high severity wildfire compared to the control model. By the end of the century, the "average" climate future results in a net reduction of 181 million metric tons of CO_2 cumulatively (under 30% high severity fire scenario) and 136 million metric tons of CO_2 under the "hot-dry" climate future. The reduction of high severity fire also reduces suppression costs from $57 to $240 million depending on the climate future for this fire scenario. The assumption of how much of future fire area will be high severity greatly affects the ability to achieve GHG reductions. For example, under a scenario in which only 10% of the future fire area burns under high severity conditions, the net climate effect is nearly neutral under the "hot-dry" climate future with a small amount (21 million metric tons) of reductions under the "average" climate future. On the other hand, if fire severity and frequency is underestimated, the savings could be far greater. Future improvements in harvested wood utilization will also greatly affect the climate benefit of this intervention.

Co-benefits improve attractiveness of intervention implementation: The interventions modeled in this study provide numerous co-benefits in terms of improved air quality, water quality, ecosystem resilience to climate change, and in some cases food production. By protecting and restoring natural vegetation cover in agricultural and rangeland systems (riparian restoration, agroforestry), water quality benefits accrue to downstream users through the retention of sediment and nutrient-rich runoff from fields. Reducing the frequency and intensity of timber harvest can provide increased habitat quality for wildlife that prefer older, more structurally complex forests, for example. Reducing the expansion of urban areas into natural habitats and agricultural lands provides numerous benefits, including bringing food production closer to markets and reduced traffic and air pollution due to shorter commute times. Finally, implementing projects to reduce wildfire risk provides numerous benefits in a climate-changed world through the protection of life and property. A characterization of these co-benefits can be found in Figure 1 and within each intervention's overviews later in the report.

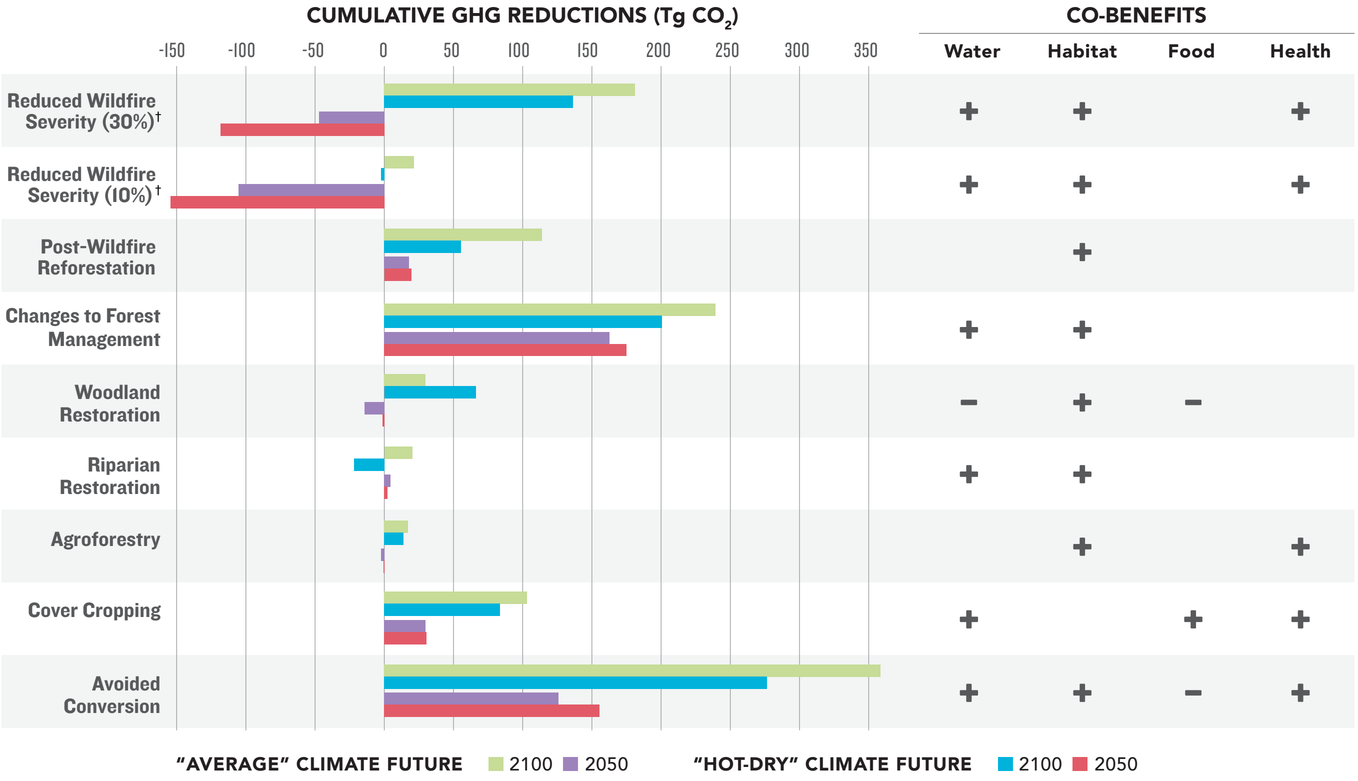
Key Implementation Recommendations

Establish an ambitious climate goal for the state's natural and working lands. Given the state's goal to become carbon neutral by 2045 and the potential for the state's natural and working lands to become an increasing net source of emissions, the state should establish an ambitious climate goal for its natural and working lands to ensure appropriate attention, accountability, and investment in these resources.

Early and aggressive implementation will provide larger climate benefits due to the time lags inherent in ecosystem response to interventions. Many of the interventions that rely on growing vegetation (mostly trees) will yield more substantial benefits the earlier they begin due to the compounding effect of tree growth—as trees grow larger their capacity to absorb more carbon dioxide increases. This is especially relevant given California's stated goal of having a climate neutral emissions profile by 2045. Natural and working lands interventions will be especially important in meeting that goal, given residual emissions likely in other economic sectors.

Dedicate sustained funding to natural and working lands for climate mitigation and associated benefits. While the state has dedicated some funding from its Greenhouse Gas Reduction Fund (GGRF) for natural and working lands investments, it has been relatively small and inconsistent compared to the scale and duration of climate investments in other sectors such as transportation and energy. While nearly $926 million has been invested in California's natural and working lands from the state's GGRF over the past six years through annual appropriations, this represents roughly 11 percent of the total $8.4 billion that has been invested across the economy.

FIGURE 1 Cumulative GHG Reductions by Intervention, Mid- and End-Century



Note: Positive and negative effects on co-benefits including water quality and quantity (Water), habitat availability (Habitat), food production (Food), and public health and resilience (Health). †The same reduced wildfire severity scenario was run twice, each using a different assumption for the percentage of high severity fire that composes a wildfire in the model (30% vs 10%). See Intervention Results for more detail.

Leverage existing programs and policies, while building new ones. In many cases, policies and programs already exist to enable implementation of the modeled interventions. In the near term, scaling up these programs using new funding sources will enable the rapid deployment of funding and technical expertise to ensure rapid implementation. Using existing landowner outreach tools and networks, such as those administered by RCDs, NRCS, CalFire, and the U.S. Forest Service can lead to increased adoption due to the legacy of trust and collaboration that underpins these programs. New programs could focus on planning at county and regional scales, and on implementation that can optimize greenhouse gas reductions across sectors as well as other important co-benefits.

Adopt a portfolio of solutions across land types, regions, economic sectors, and ownership types. Given the high uncertainty inherent in climate change scenarios, adopting an approach that spreads the risk across different land uses and geographic regions will make it more likely that place-based climate impacts and disturbances will not reverse beneficial actions. While forests certainly represent the largest opportunity to store carbon in aboveground biomass and grasslands represent a large potential belowground sink, there will be geographic differences in fire frequency, drought, and other processes that make investing in a diversity of implementation areas an effective risk management strategy.

ENDNOTES

1 Griscom, B. W. *et al.* Natural climate solutions. *Proc. Natl. Acad. Sci.* **114**, 11645–11650 (2017).

2 Cameron, D. R., Marvin, D. C., Remucal, J. M. & Passero, M. C. Ecosystem management and land conservation can substantially contribute to California's climate mitigation goals. *Proc. Natl. Acad. Sci.* **114**, 12833–12838 (2017).

3 State of CA. *California Climate Investments Annual Report.* (2017). at <https://arb.ca.gov/cc/capandtrade/auctionproceeds/cci_annual_report_2017.pdf>

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Full report at www.next10.org/land-carbon