Received: 15 February 2024 | Revised: 24 May 2024 | Accepted: 24 June 2024
DOI: 10.1111/csp2.13232

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access
WILEY

An approach to designing efficient implementation of 30×30 terrestrial conservation commitments

Carrie A. Schloss[1] | **D. Richard Cameron**[1,2] | **Bradley Franklin**[1] | **Christoph Nolte**[3] | **Scott A. Morrison**[1]

[1]The Nature Conservancy, San Francisco, California, USA
[2]Pachama, San Rafael, California, USA
[3]Department of Earth & Environment, Boston University, Boston, Massachusetts, USA

Correspondence
Carrie A. Schloss, The Nature Conservancy, 620 Davis Street, San Francisco, CA 94111, USA.
Email: cschloss@tnc.org

Abstract

In response to biodiversity declines worldwide, over 190 nations committed to protect 30% of their lands and waters by 2030 (hereafter, 30×30). Systematic conservation planning and return on investment analysis can be helpful tools for determining where protection efforts could deliver the most efficient and effective reserve design, and supporting decision-making when trade-offs among objectives are required. Here, we propose a framework for efficient "30×30" implementation and apply it to the state of California (USA). Because conservation of a region's full suite of biodiversity is the primary objective of the global initiative, we prioritized representation in our analysis. We used Zonation to identify networks that close the gap in representation of major habitat types in California's protected area network and that also conserve the places important for biodiversity or climate change mitigation. We identified networks that are efficient relative to metrics likely to be important in implementation including land acquisition cost, number of transactions, and conservation benefit per hectare, and we illustrate not only trade-offs associated with these metrics but also differences in the co-benefits achieved. Five of the eight major habitat types in California are not currently protected at a 30% level statewide, and if representation was achieved solely through private land acquisition, targets could be met for as little as $5.84 billion, with as few as 364 transactions, or with 2.18 million additional conserved hectares. Implementation of 30×30 will likely require more flexibility than a single network design. A "no regrets" action would be to protect properties that were prioritized across all networks and additional implementation should include properties with characteristics of any of the individual networks. Our analytical framework and implementation guidance can be applied to other geographies and jurisdictions to increase the likelihood of both meeting 30×30 targets and delivering the conservation benefits they aim to secure.

KEYWORDS
30×30, conservation planning, efficiency, representation, reserve design, trade-offs, zonation

1 | INTRODUCTION

In response to concerns about global biodiversity loss, more than 190 countries committed to protect at least 30% of the earth's lands and waters by 2030 (hereafter, 30×30) as Target 3 of the Kunming-Montreal Global Biodiversity Framework (CBD, 2022). A multitude of initiatives before and since have endeavored to develop frameworks to guide and track progress towards those targets, including definitions of what constitutes "protection," criteria for prioritizing additional investments, and methodologies for monitoring and reporting (e.g., Bateman et al., 2023; Carroll et al., 2022; Carroll & Ray, 2021; Dreiss et al., 2022; Dreiss & Malcom, 2022; Gallo et al., 2023; Jetz et al., 2022; Oshun & Grantham, 2023; Simmons et al., 2021; Venegas Li et al., 2023). Given the severity and urgency of the biodiversity, climate, and sustainability crises (Crossley et al., 2020; IPCC, 2023; Laliberte & Ripple, 2004; Muths, 2012; Rockström et al., 2009; Rosenberg et al., 2019), and the relatively short timeframe remaining to meet 2030 targets, it is critical that the myriad societal actors implementing 30×30 use approaches that increase the likelihood their commitments will indeed be fulfilled and that the effort will deliver the needed conservation impact.

Systematic conservation planning is widely recognized as a best practice for prioritizing the allocation of limited resources to achieve conservation goals (Groves & Game, 2016; Margules & Pressey, 2000). Often, the output of a systematic conservation planning process is an optimized design of a network of land and waters that if managed for conservation would sustain the region's biological diversity and support ecological processes. Representation of the full diversity of habitats in a network of connected, conserved lands is recognized as a foundational planning principle for biodiversity conservation (Dinerstein et al., 2019; Kukkala & Moilanen, 2013; Margules & Pressey, 2000; Olson & Dinerstein, 1998). Several analytical tools have been developed to support the design of efficient, representative networks, such as Marxan (Ball et al., 2011) and Zonation (Moilanen, 2007). Seeking representation at the ecological system or major habitat level (coarse-filter targets) is often a starting place in these analyses because they capture biogeographic differences and encompass many species and population-level (fine-filter) targets within those habitats (Groves, 2003; Halpin, 1997; Hunter et al., 1988; Noss, 1987).

Planning for multiple objectives has become increasingly important as more conservation programs aim to provide ecosystem services, including carbon sequestration, in addition to biodiversity conservation (Bateman et al., 2023; Carroll & Ray, 2021; Dreiss & Malcom, 2022; Nelson et al., 2008; Polasky et al., 2012). This has raised the question of whether biodiversity conservation and securing the delivery of ecosystem services are spatially synergistic goals or involve trade-offs (Chan et al., 2006). The degree that both can be simultaneously advanced likely depends on the ecosystem and the ecosystem service of interest (Chan et al., 2006). For example, one study in Minnesota found a high degree of overlap between the optimal area for ecosystem services and biodiversity (Polasky et al., 2012), whereas another in Oregon showed that pursuing carbon sequestration and species conservation would likely require different designs (Nelson et al., 2008).

Incorporating the costs of land acquisition and stewardship in conservation site selection can dramatically increase cost-effectiveness relative to approaches that focus solely on conservation targets (Ando et al., 1998; Polasky et al., 2001). The magnitude of potential gains in cost-effectiveness when using a return on investment (ROI)-centered approach is linked to the high variability of land costs: it has been observed that land costs, along with threats to biodiversity, typically vary significantly more than the distribution of species richness or other biodiversity metrics (Bode et al., 2008; Murdoch et al., 2007; Polasky, 2008). This fact creates opportunities to identify lower-cost properties and therefore increase the ROI of conservation programs, although high-resolution land value data may be required to identify these opportunities (Nolte, 2020). Land value alone also does not capture transactional costs for each property, such as the capacity required to evaluate, obtain funding, transfer legal ownership, and develop a management plan (Naidoo et al., 2006). Consequently, for some conservation actors reducing the number of transactions required to meet the conservation objective is an explicit design principle.

To achieve the desired impact of 30×30 commitments, substantial effort and investment will be required. A robust optimization framework can inform resource-efficient decision-making. Here, we demonstrate and apply such a framework to the state of California, USA. The framework is premised on two key assertions. First, because 30×30 commitments were motivated in response to the global biodiversity crisis, core principles of systematic conservation planning need to be applied. Thus, we considered the representation of major ecosystem types and application of network design principles to be foundational in this effort. Second, because of the urgency of the extinction and climate crises, as well as the time-boundedness of the commitments, we incorporated analyses that would allow for explicit consideration of implementation efficiency, comparing alternative network designs by various types of efficiency, identifying opportunities for multi-benefit solutions, and estimating the funding that will be required to meet the commitment in order to inform budgeting.

1.1 | Study area and policy context

California is home to one of the 36 global biodiversity hotspots, regions with high biodiversity that are threatened by conversion (Myers et al., 2000). California has some of the highest richness of unprotected, range-restricted imperiled species in the United States (Hamilton et al., 2022) and also has been experiencing extensive land conversion with over a million acres of natural land converted to human uses between 2001 and 2017 (Conservation Science Partners, 2019).

In 2020, an executive order by the state's governor committed California to conserve 30% of its lands and coastal waters by 2030 (EO N-82-20 State of California, 2020). The executive order identified three key objectives to guide the state in this commitment: protecting and restoring biodiversity, expanding equitable access to nature and its benefits, and conserving the places that help California achieve carbon neutrality and/or build climate resilience.

Here, we focus on the role of private land conservation in implementing the terrestrial component of California's 30×30 commitment. We use Zonation to identify networks of privately owned land that, if conserved alongside currently protected lands, would encompass at least 30% of all major terrestrial habitat types statewide. These networks factored in one of two additional objectives: biodiversity protection, including areas that provide habitat connectivity, and climate change mitigation, specifically carbon storage in soils and living biomass. We describe the characteristics and geographic distributions of networks designed to achieve targets via the smallest area (area-efficient), the least cost (cost-efficient), or the fewest transactions (transaction-efficient). We quantify the cost of each network and the co-benefits achieved to illustrate the trade-offs and opportunities for flexible and inclusive implementation and to help the state plan for appropriate budgets to succeed in this effort.

2 | METHODS

2.1 | Framework

Below, we outline the components of an analytical framework for the design of 30×30 and apply those methods to the state of California.

2.2 | Representation and network design

2.2.1 | Gap analysis

To determine how well major natural, non-aquatic habitat types were already represented by existing conserved lands statewide, we conducted a gap analysis using the broad 13-class California Wildlife Habitat Relationship (CAL FIRE, 2015) vegetation classification to determine the distribution and extent of California's major habitats. We considered all IUCN category I-VI lands (Dudley, 2008), state parks, Areas of Critical Environmental Concern (ACEC) (PAD-US, USGS, 2020), and conservation easements (GreenInfo Network, 2022a) to be "conserved lands" (Figure 1). We calculated the area of each habitat type statewide, the area already conserved, and the additional area needed to conserve 30% of the habitat's distribution in California.

2.2.2 | Habitat targets

To set percentage targets for habitat types, we divided the area of each major habitat still needed to ensure that the protected area network covers 30% of each habitat by the total area of the analytical extent for the spatial prioritization (i.e., all privately owned, non-conserved lands greater than the minimum planning unit area threshold) (Appendix S1, Figure 1).

2.2.3 | Spatial prioritization□Zonation

Zonation is a spatial prioritization software tool (Moilanen, 2007) widely used for conservation planning (e.g., Bateman et al., 2023; Howard et al., 2018; Kreitler et al., 2015; Stralberg et al., 2019) that addresses complementarity of conserved lands, ranks the entire landscape,

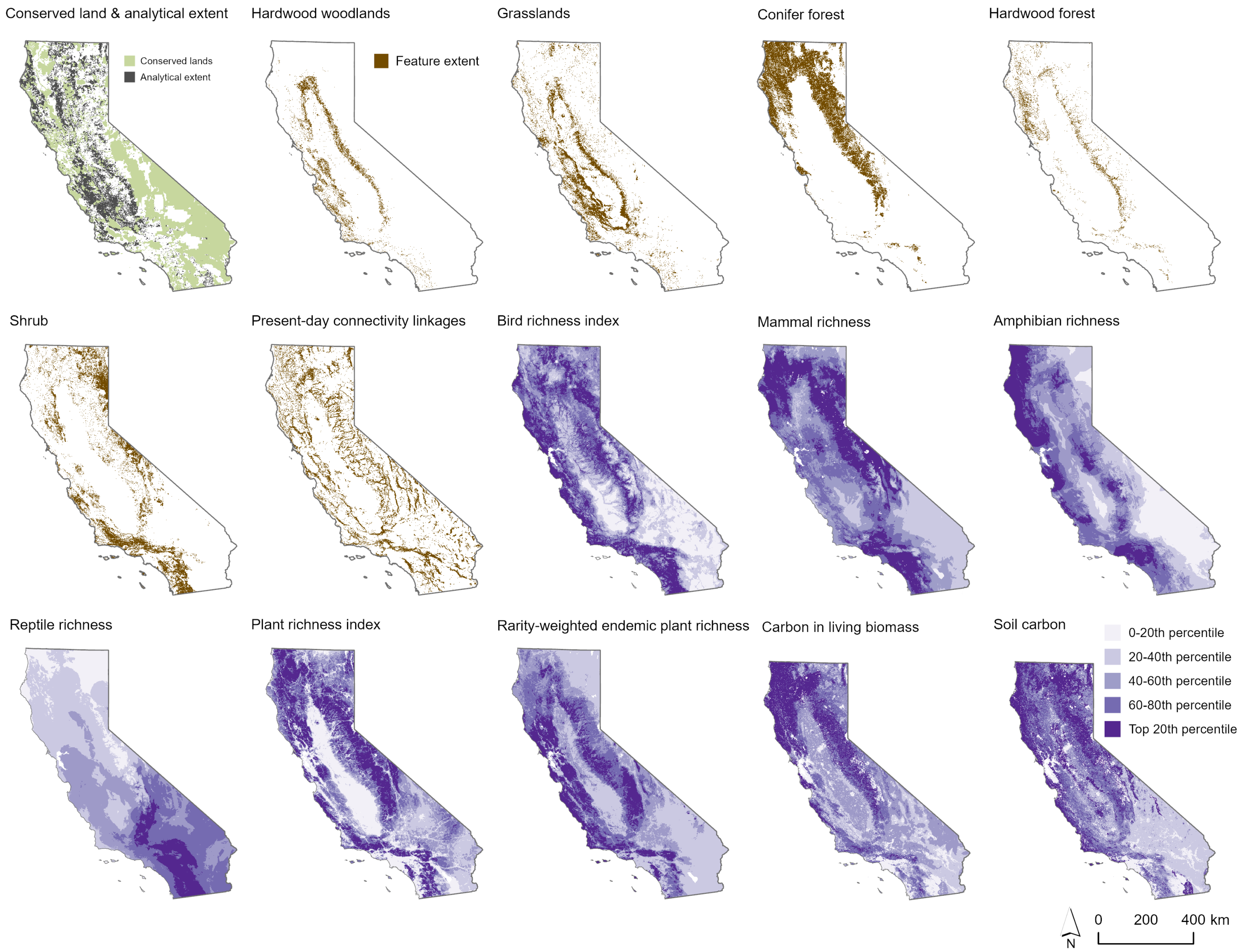

FIGURE 1 Zonation and gap analysis input layers. Maps of richness and carbon are displayed in quintiles.

and allows for the combination of multiple types of conservation asset data. Zonation ranks the landscape by iteratively removing planning units for which removal corresponds with the smallest marginal loss of conservation value.

We used the target-benefit function in Zonation to identify efficient networks that achieve 30% representation of California's major, non-aquatic habitat types. The target-benefit function uses proportional targets to approximate a minimum set solution (Moilanen et al., 2014). In this cell-removal process, just before any target is violated via the next successive cell removal, the target-benefit function results in a near-optimal minimum-set solution (Moilanen, 2007).

2.2.4 | Planning units

We used all large, privately owned properties in California as planning units because properties are the units on which many conservation actions can be applied whether through land use planning, land-owner incentives, conservation easements, or fee title acquisitions. Additionally, the variable size of properties allowed us to evaluate opportunities and trade-offs for conservation action (e.g., larger properties mean fewer transactions are required but at a higher overall cost per transaction). We defined properties as aggregations of near-adjacent (i.e., <0.75 miles apart) parcels that share common ownership using a fuzzy match on ownership name (Appendix S2). We used 202.3 hectares (500 acres) as a minimum size property for analytical feasibility and with the assumption that most transactions that support biodiversity conservation and climate change mitigation and resilience will likely occur on somewhat large properties. We removed properties with more than 70% of their area within an easement (per CCED, GreenInfo Network, 2022a) or that fell within public ownership or conserved land (per CPAD, GreenInfo Network, 2022b or PAD-US, USGS, 2020) from this set of planning units. We used the

Conservation Science and Practice
A Journal of the Society for Conservation Biology
Open Access
WILEY

combined geography of these large, privately owned properties as the extent of the Zonation analysis to reduce processing time. Multi-use public lands (e.g., U.S. National Forests and most U.S. Bureau of Land Management lands) and military bases were not included in the set of "conserved lands," nor are they available as lands to include in meeting the objectives described below.

2.2.5 | Multiple objectives

We used Zonation to rank this landscape for its contribution to habitat representation combined with one of two alternate objectives: (1) biodiversity protection as measured by species richness by taxonomic group and connectivity or (2) climate mitigation as measured by carbon storage. We refer to these objectives as "biodiversity protection" and "climate mitigation" hereafter.

Areas likely to support connectivity (Cameron et al., 2022) and the greatest number of species of birds, mammals, reptiles, amphibians, plants, and the rarest endemic plants (Kling et al., 2019; Stewart et al., 2016; Veloz & Jongsomjit, 2012; Wright et al., 2013) are prioritized in the biodiversity protection objective and areas with the highest carbon storage both in living biomass and in soils as soil organic carbon (Sleeter et al., 2019) are prioritized in the climate mitigation objective (Appendix S1, Figure 1).

For this broader set of conservation assets used in the prioritization that go beyond habitat representation targets (e.g., species richness, connectivity linkages, ecosystem carbon), we set the conservation target at 1% for each individual feature (Appendix S1). We set these targets low so that each feature would contribute to the marginal value of every cell throughout the entire cell removal process and would result in networks with planning units with a high richness of every feature, weighted by occurrence across the analytical extent. We used an established model of landscape connectivity (Cameron et al., 2022) to prioritize planning units selected in the biodiversity protection objective, rather than implementing one of Zonation's methods to prioritize network connectivity (Di Minin et al., 2014).

2.3 | Efficiency, trade-offs, and budget

For both the biodiversity protection and climate mitigation objectives, we ran Zonation with different cost parameters to identify networks that are prioritized under different types of efficiency: area, cost, or transaction. To create an area-efficient network, we make use of the fact that in Zonation the target-benefit function automatically uses the total area of a planning unit as a "cost" layer when planning units are applied. The marginal value of a planning unit with this parameterization is the total additive conservation value across all features (based on the remaining distribution of each feature) divided by the total area of the planning unit. To identify a cost-efficient network, we used a modeled 30 m estimate of cost per hectare (Nolte, 2020), converted to cost per pixel, and aggregated to 90 m. We first modified the 30 m cost raster by filling in any zero-value pixels which correspond to roads and water bodies, within the boundaries of a private property with the area-weighted average cost per hectare of the property. To identify a transaction-efficient network, we used a raster of 1 divided by the number of grid cells on the property as the cost. Zonation uses the sum of all the values in a "cost" raster to calculate the cost of a planning unit. Therefore, using the inverse of the total number of grid cells, the total planning unit cost for analysis would be 1. With this parameterization, the full aggregate conservation value for a property would be used for evaluation, therefore, larger properties have a higher likelihood of higher aggregate conservation value with no penalty for their higher cost or larger area.

2.3.1 | Network comparison

After ranking the landscape with Zonation, we determined the minimum network at which all habitat representation targets were met by iteratively adding properties to a network according to the highest Zonation rank until the target for every major habitat type is achieved. We then calculated the total size, estimated cost of acquisition, and number of transactions of each of the six networks prioritized for different objectives and with different efficiency goals. Here, cost refers to fee title acquisition. Easement costs are usually a proportion of the acquisition cost, but this proportion is variable and estimating both the percentage of networks likely to be easements and the variable cost of these easements is beyond the scope of this analysis. In addition, we calculated the average land value per hectare, average transaction size, average cost per transaction, and proportion of each habitat type within the network. We calculated the Jaccard-similarity index to determine similarities in networks across planning objectives and type of network efficiency. For visualization purposes, we mapped the network at a 647.5-hectare (1600-acre) hexagon resolution by identifying any hexagon that intersects with a property in the network.

Given the model results generated, we identified properties that appear in every network regardless of conservation objective or network efficiency. We then summarized the average size, cost, habitat composition, and co-benefits covered by these properties common to all networks to evaluate the potential for "no-regrets" opportunities for 30×30 investment.

2.3.2 | Co-benefits evaluation

After identifying the six prioritized networks, we quantified the coverage of a suite of co-benefits (Appendix S3) for additional features that were not used in our prioritization that are likely to directly support or be complementary to California's 30×30 three key objectives (EO N-82-20 State of California, 2020). Co-benefits included measures related to equity and access, community risk and resilience, biodiversity and climate resilience, modeled risk of conversion to development, and adjacency to conserved lands. We then scored each network for its ability to achieve co-benefits by comparing the quantity of additional assets covered by the network to the maximum amount of that asset covered by any network. We considered any network within 5% of the maximum to be of the same rank and assigned a subsequent rank for each 5% increment below the maximum. We assigned a rank of zero if the co-benefit coverage was less than 50% of the maximum coverage. This method captures both rank and magnitude of difference.

3 | RESULTS

In this section, we first identify the statewide gap in protected area by major habitat type and then give an overview of results from Zonation, discussing the degree of similarity between the identified efficient networks. We then detail the results of each form of efficiency, starting with metrics of total area, total estimated acquisition cost, and number of transactions per network and then comparing the co-benefits corresponding to each type of network. Lastly, we identify the attributes of properties that overlap among all networks.

3.1 | Representation: Gap analysis and habitat targets

Of the 13 major habitat types classified by California Wildlife Habitat Relationships, eight are non-aquatic and natural. Three of those habitats, conifer woodland, desert shrub, and desert woodland, are already conserved at 30% (41%, 66%, and 76% respectively; Appendix S4), however, the remaining habitats have protection coverage ranging from 14% to 28% (Appendix S4). 1.9 million hectares of protection would be needed to represent the remaining five habitats, conifer forest, hardwood woodland and forest, grassland, and shrub at 30% (Appendix S4).

3.2 | Network design and efficiency

The analytical extent of the Zonation analysis covers 8.9 million hectares, representing the combined area of privately owned, unprotected properties greater than the minimum size threshold, covering 22% of California's land area. Prioritized networks of private lands cover 24%–34% of the analytical extent (5.3%–7.5% of statewide land area) depending on the objective and network efficiency. Over 75% of each network consists of a combination of grassland, hardwood woodland, and conifer forest. Closing the representation gap could be achieved in a network of large properties with as few as 2.18 million additional conserved hectares, for as little as \$5.84 billion, or with as few as 364 transactions (Table 1).

Networks that achieve representation with different planning objectives (i.e., biodiversity protection vs. climate change mitigation) were more similar to each other than networks planned for different types of efficiency (Jaccard index range 41–90.7 for the former and 6–22 for the latter; Appendix S5). Therefore, in our descriptions of the networks below, we combine the planning objectives and compare networks by type of efficiency.

3.3 | Area-efficient network

The area-efficient networks for both biodiversity protection and climate change mitigation (Figure 2a,b) consist of many (>2000) small properties (average size 956–1024 ha) that are dense in terms of conservation value (Table 1). These properties are often close to major urban centers such as within the San Francisco Bay Area, the Sacramento foothills, and the southern coast of California where property sizes are relatively small and property costs are relatively high (Figure 2a,b). Many properties are also on the north coast, especially for the climate change mitigation objective. Although the area-efficient networks are the smallest in total area (2.18–2.21 M ha), they also have the highest total estimated cost of acquisition (>\$19B), highest land value per hectare (>\$8800/ha) and the most transactions (Table 1, Appendix S6). The area-efficient networks are more sensitive to planning objective than networks with other cost parameters as is reflected by the lowest Jaccard Index score (Appendix S5).

TABLE 1 Comparison of network characteristics prioritized for different conservation objectives and different types of efficiencies.

Key objective	Type of efficiency	Hectares	Cost	# of transactions	Average property size (ha)	Average property cost	Average $/ha
Protect biodiversity	Area-efficient	2.21 M	$19.48B	2312	956	$8.43 M	$ 8816
	Cost-efficient	2.35 M	$6.15B	1851	1269	$3.32 M	$ 2618
	Transaction-efficient	3.08 M	$16.55B	376	8196	$44 M	$ 5371
Mitigate climate change	Area-efficient	2.18 M	$19.97B	2133	1024	$9.36 M	$ 9143
	Cost-efficient	2.25 M	$5.84B	1702	1320	$3.43 M	$ 2600
	Transaction-efficient	2.96 M	$16.14B	364	8145	$44.35 M	$ 5445

Note: Every network meets all five habitat representation targets.

3.4 | Cost-efficient network

The cost-efficient network (Figure 2c,d) generally includes properties further from both the coast and major metropolitan areas. It is the only network to include properties in the desert (albeit for biodiversity only) and in the Modoc Plateau in the north-eastern corner of the state. These networks are much less expensive (<$6.15B) with an average land value per hectare around $2600 (Table 1, Appendix S6). These networks have a relatively high number of transactions (1851 and 1702 for biodiversity protection and climate mitigation, respectively).

3.5 | Transaction-efficient network

The transaction-efficient network (Figure 2e,f) consists of fewer, very large properties concentrated in the inner-central coast and the north coast and the northern foothills. The network achieved representation with few transactions (<400), but with very large properties (average size >8000 hectares) that cost over $44 million each on average and with a total network size of roughly 3 million hectares (Table 1). Despite the high cost of each transaction, the average land value of around $5400 per hectare is intermediate compared to other networks (Table 1, Appendix S6). The transaction-efficient networks have the highest proportion of conifer forest (41%) and lower proportions of hardwood woodland (13%) and hardwood forest (6%) compared to other networks (Appendix S6). Overall, this network has the highest rank for coverage of co-benefits (Table 2).

3.6 | Co-benefit comparison

The transaction-efficient networks, which cover the largest overall area and include the largest properties, had the highest percentage of properties adjacent to existing conserved lands, and also attained the most co-benefits across all metrics except for climate migration routes and siting in areas of no park access, both of which the area-efficient networks better cover. The cost-efficient networks are the least effective at achieving co-benefits (Table 2), the least likely to be at risk of development (<7% of properties), and include the lowest percentage (35%) of properties in places that lack park access (Appendix S6). Although the networks differ in the overall area of resilient lands and climate migration routes, 88%–95% of properties in each network are within a climate migration route or within resilient landscape. The percent of properties sited in disadvantaged communities (i.e., vulnerable populations that face a disproportionate pollution burden; Appendix S6) is least sensitive to efficiency type though all of the networks have a low proportion of properties within this designation. There is the most disparity in coverage by different networks for water resources including groundwater-dependent ecosystems, wetlands, and floodplains.

3.7 | Network overlap

The intersection of the six networks (Figure 3) indicates a potential core set of properties where multiple objectives can be met at every measure of efficiency. There are 47 properties totaling 200 thousand hectares and approximately $600 million that are included in the area-efficient, cost-efficient, and transaction-efficient networks for both the biodiversity protection and climate mitigation objectives. These properties average 4256 hectares in size at an average cost of $3000 per hectare or $12.9 million per transaction. This subset of properties are primarily clustered in the inner-central coast with others in the Tehachapi Mountains and in the foothills surrounding the northernmost part of the Central Valley. They consist primarily of grassland and hardwood woodland,

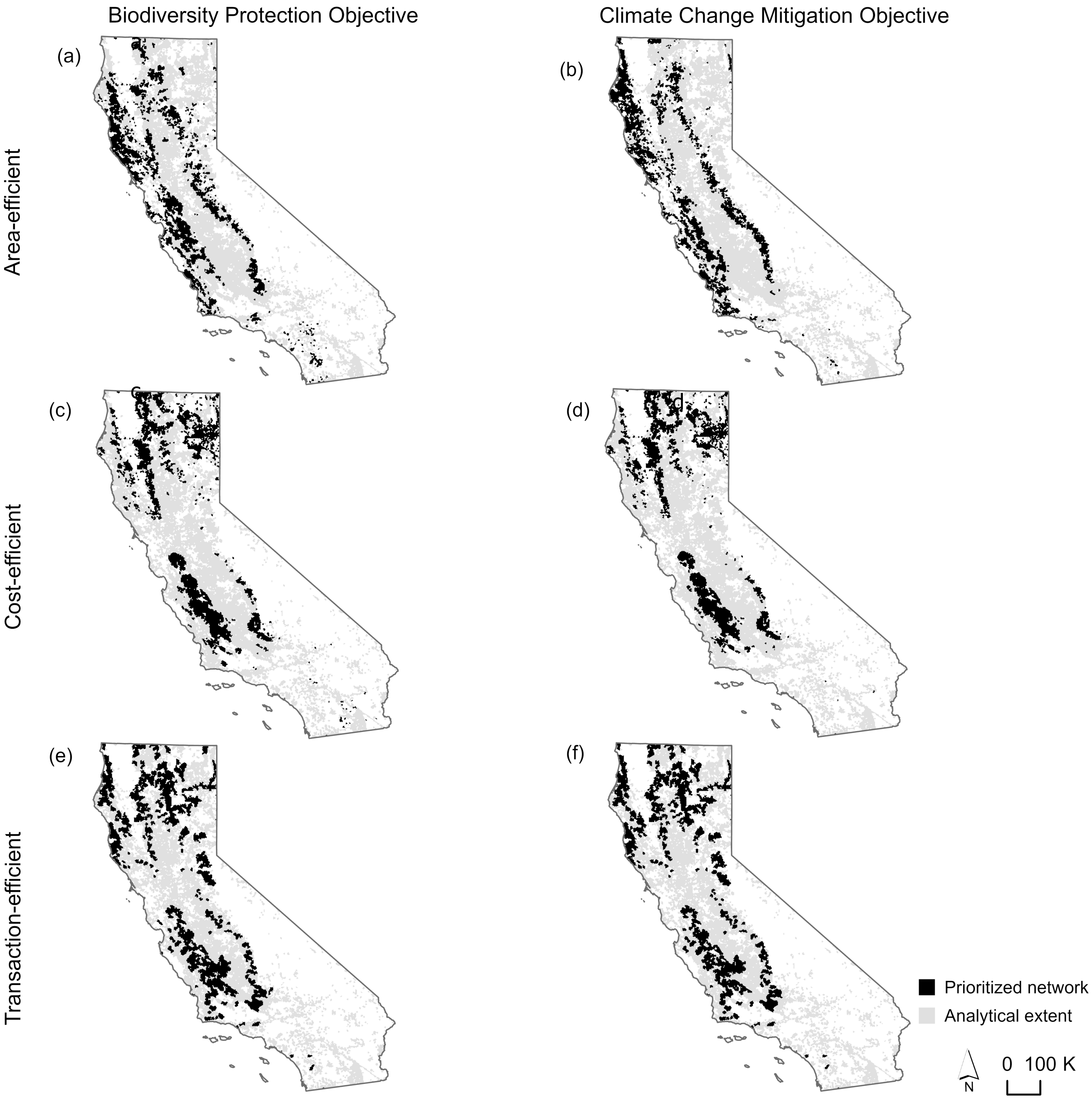

FIGURE 2 Maps showing 647.5 hectare hexagons that intersect with a property within the networks of large, unprotected properties prioritized from Zonation-ranked landscapes that would close the representation gap for all major, natural habitat types and additionally prioritize species richness and connectivity (a, c, e) or carbon storage (b, d, f) in an area-efficient (a and b), cost-efficient (c and d), or transaction-efficient (e and f) networks. Gray hexagons on all maps indicate hexagons that intersected with the analytical extent but that did not intersect with the prioritized network.

covering 40% and 28% of the total area of these properties combined respectively. About 45% of these properties would be in locations with no park access within a half mile, while 75% would be investments in low-income communities, and 28% would be investments in disadvantaged communities with vulnerable populations that face a disproportionate pollution burden. 83% of these properties are adjacent to conserved lands.

4 | DISCUSSION

Over 28 million hectares of lands in California fall outside of the lands categorized herein as "conserved," which leaves a great deal of flexibility as to where additional protection can occur to meet the state's 30×30 targets. This flexibility provides myriad opportunities not only to design a more representative network of

TABLE 2 Ranked comparison of co-benefits of networks prioritized for different conservation objectives and types of efficiency.

		Protect biodiversity objective			Mitigate climate change objective		
Co-benefit type	**Co-benefit feature**	**Area-efficient**	**Cost-efficient**	**Transaction-efficient**	**Area-efficient**	**Cost-efficient**	**Transaction-efficient**
Conservation planning context	Adjacent to conserved lands	7	8	10	6	8	10
	At risk of development	10	6	10	10	6	10
Community risk and resilience	Fire risk	6	5	10	6	4	10
	Wildland-urban interface	8	4	10	8	4	10
	Flood risk	0	0	10	0	0	6
Equity and access	Low-income communities	5	10	10	5	10	10
	Disadvantaged Communities	7	9	10	6	9	10
	Drinking water source Watersheds	6	6	10	2	5	10
	Low park access	9	4	9	10	4	9
Biodiversity and climate resilience	Wetlands	0	8	10	0	6	9
	Groundwater-dependent ecosystems	2	0	10	5	0	6
	Well-connected landscapes	3	5	10	5	5	10
	Unprotected imperiled biodiversity	10	7	10	6	6	10
	Resilient landscapes	6	7	10	6	6	10
	Climate migration routes	10	6	7	3	5	6
Total score		6.3	5.6	9.3	5	5	8.6

Note: Highest scores (10) indicate the maximum quantity of the co-benefit covered by any network, and subsequently lower scores were assigned for each 5% increment below the maximum. A rank of 0 was assigned if the co-benefit coverage was less than 50% of the maximum coverage achieved by another network. Darker shades of gray indicate higher ranks.

conserved lands but also additionally focus on actions that contribute to the California Executive Order's three key objectives, including protecting the most biodiverse places, wildlife linkages and climate migration routes, conserving carbon sequestration in soils and vegetation, and improving equitable access to nature and the broad array of benefits it provides to California communities.

The analytical framework we present can be used to identify such opportunities and provide helpful information to decision-makers when they face trade-offs between different objectives. By using representation as a foundational planning principle, the framework increases the likelihood that implementors of 30×30 will meet the primary conservation objective of the initiative. And by including explicit analytics on efficiencies, it can help them meet the objective in the face of limited time and resources. By offering a variety of flexible and inclusive network designs, versus a single idealized network design, our framework allows for a transparent evaluation of trade-offs in implementation, which is essential given the complex social arena in which most conservation investments get made. We offer guiding questions to consider during opportunity evaluation based on opportunities present in each of the six networks (Figure 4).

4.1 | Implementation

We found that network geography is more sensitive to the type of efficiency than it is to the chosen planning objective. The high degree of similarity between networks that prioritized biodiversity protection or climate change mitigation indicates ample opportunity for multi-objective conservation. Still, we found there is no single

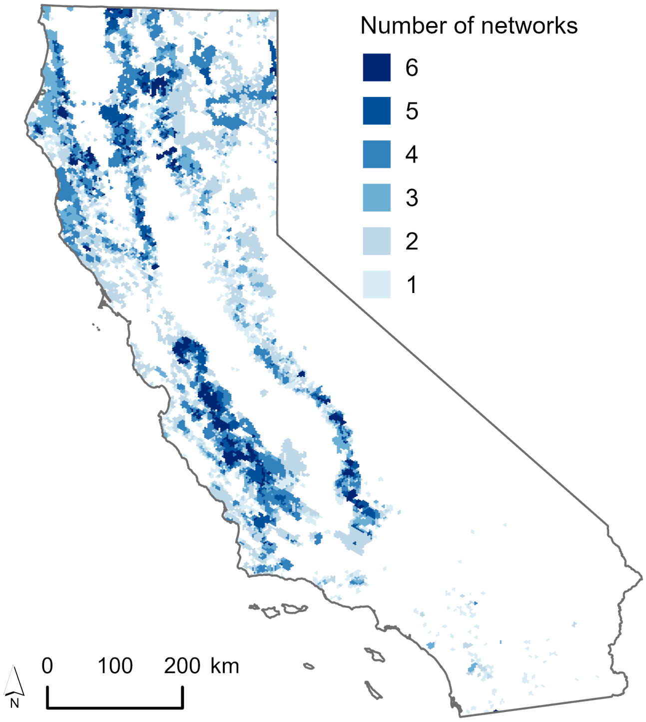

FIGURE 3 Map showing the number of Zonation prioritized networks that intersect with a 647.5 hexagon. All hexagons shown are in at least one network (light blue) with successively darker shades of blue indicating inclusion in 2–5 networks. The darkest blue hexagons include properties prioritized in all six networks regardless of the type of efficiency or planning objective.

ideal network design for implementation of California's 30×30 commitment. There will always be trade-offs, whether it be in land costs, transaction costs, the opportunity cost of alternative land uses, additionality from risk of conversion, participation by all regions and actors, or ability to advance multiple objectives. For example, the cost-efficient network may seem appealing due to its more attainable budget ($5.84–$6.15 billion); however, there are many trade-offs associated with this network. Less than 7% of properties in the cost-efficient networks are in areas projected to be at risk of development or densification by 2050. This indicates that land uses may be less likely to change by 2050, and therefore, conservation intervention may not be necessary to conserve existing biodiversity values (Maron et al., 2013). Moreover, the cost-efficient networks were less likely to achieve additional co-benefits than other networks, and they were absent in several regions of the state due to higher land values (e.g., along the California coast, in the central-Sierra foothills, and areas surrounding large metropolitan regions) which could be limiting to inclusive participation from regionally focused organizations and agencies.

In contrast, the area-efficient network has many properties in regions absent or scarcely represented in the cost-efficient network, providing options for corresponding local and regional organizations and agencies to participate. Proximity to population centers also makes properties in these networks potentially important for access as this network has the highest percentage of properties in places that currently lack park access. However, these networks have a smaller percentage of properties in low-income communities (Appendix S6), so the additional access achieved through protection of this network may not necessarily improve measures of equity in access. The properties in this network also are less likely to be adjacent to currently conserved lands, are smaller than properties in other networks, and may therefore result in isolated protected areas with the potential for higher management costs per hectare (Adams et al., 2012; Parker, 2012) and a lower potential for climate resilience (Parker, 2012). The overall budget and the quantity of individual transactions required to implement this network also may reduce the feasibility of full network implementation.

The transaction-efficient network seems appealing for implementation because it has the greatest capacity for achieving multiple objectives with a more practicable number of transactions to complete before 2030 and with an intermediate land value per hectare (approximately $5400 per hectare). However, the large size of each property (>8000 ha) makes the total cost of each transaction (> $44 million) over five times the cost of transactions in the other networks, and therefore may require collaboration of many conservation actors and multiple funding sources.

4.2 | Network overlap

Although there was not a single ideal network design in our analysis, the overlap of all of the networks could be a good place to spend the first $600 million allocated towards 30×30 implementation. There are 47 properties that are a part of any network regardless of planning objective or network efficiency, making up over 200,000 hectares. The per-hectare land value is low ($3000) and 19% of these properties are at risk of conversion to development. This subset of properties may be an ideal place to begin implementation because these are somewhat large properties, but with an average cost of a quarter of the price of the transaction-efficient network (average size 4256 hectares; average cost $12.9 million). These properties align well with foundational network design principles such as advancing complementarity and representation, and the expansion of the existing conserved network. 83% of properties in this subset are adjacent to already conserved lands, so investment will not result in isolated habitat patches.

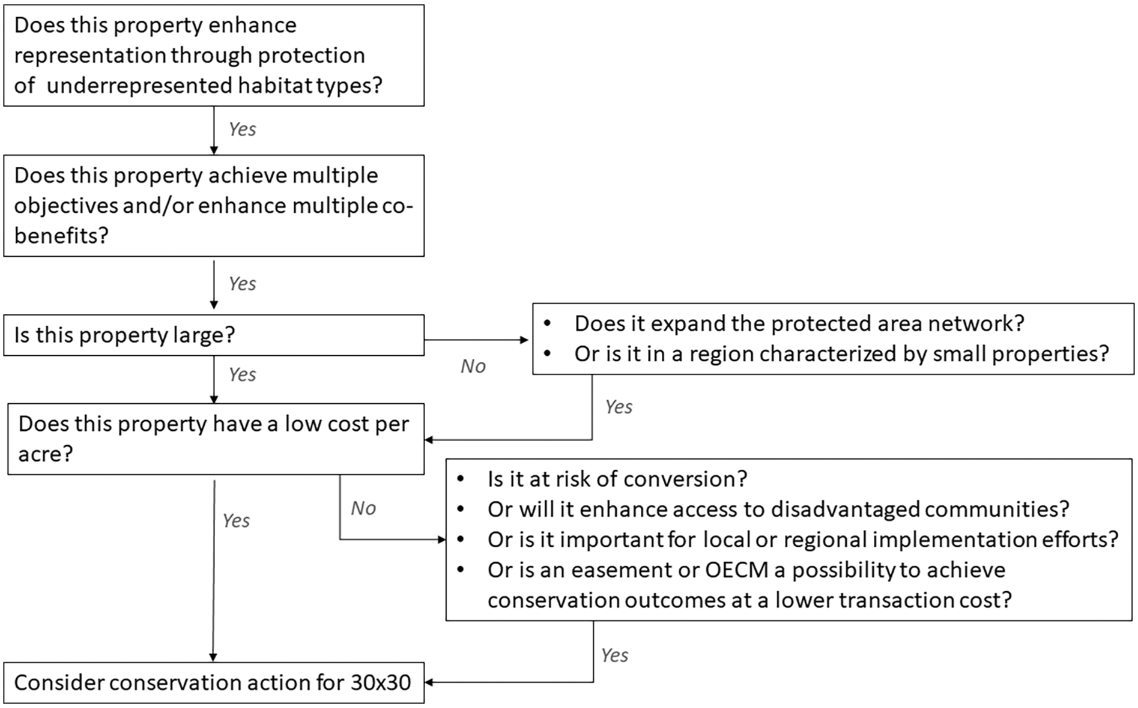

FIGURE 4 Guiding questions to consider tradeoffs and opportunities for efficient and effective implementation of 30×30.

4.3 | Equity and access

Although many properties in these networks (58%–85%) are in low-income communities, very few of the properties (6%–28%) are in disadvantaged communities defined by the combination of population vulnerability and pollution burden. For this latter population, nature-based solutions and equitable distribution of access to nature are particularly important and relevant to alleviating the inequity in the exposure risk to pollution these populations face. Because of the importance of improved access to both nature and its benefits in these disadvantaged communities in particular, the subset of properties that were within a disadvantaged community and were a part of any of the six networks may also serve as a good focal point of initial investment. There are 538 properties with an average cost per hectare of $4200 and an average property size of 2400 hectares that are within any prioritized network and within disadvantaged communities. The subset of properties totals 1.3 million hectares at a cost of $5.5 billion. Nearly 50% of this network is grassland and nearly 20% of the properties may be at risk of conversion to development.

4.4 | Risk of conversion

Because implementation will not occur all at once and because 30×30 is just the beginning of a longer trajectory and more ambitious goal to stem biodiversity decline, a first step could be to protect properties more likely to be at risk of conversion. In these example networks, the proportion of properties at risk of conversion is low (6.8%–28.8%). Bringing modeled risk of conversion into the Zonation parameterization and driving Zonation to prioritize properties at risk could address this issue, however, there will be tradeoffs because conversion threat is correlated with land value (Costello & Polasky, 2004). Within all properties within the analytical extent that are at risk of conversion, there is not enough habitat coverage of hardwood forest, conifer forest, or hardwood woodland to meet representation targets. The subset of properties at risk of conversion, greater than the minimum size threshold, and that have any amount of these three habitat types totals just over 2 million hectares across 1642 properties. While this subset has an overall size and number of properties within the range of the Zonation priority networks, the total price would be $35 billion dollars, seven times more expensive than the cost-efficient network, and with an average price per hectare of $17,000. Although these properties may face the most imminent conversion threat, the price of this network makes implementation by 2030 infeasible and investment would only achieve representation targets for one of the five under-protected major habitats.

4.5 | Using this analysis

The state has identified 10 pathways to achieve 30×30, of which land acquisitions and easements are only two (CNRA, 2022). This analysis can help identify regions where certain pathways are most applicable. For example, properties in only the area-efficient network are small, conservation-dense properties that are more expensive on average than properties in other networks. For these properties, accelerating regional conservation by resourcing local conservation organizations would be an important pathway. Voluntary easements could also be a valuable tool to reduce the cost of conservation action on these properties, but in areas where park access enhancement is needed for low-income or disadvantaged communities direct land acquisition is a better approach as open public access would enhance equitable access to parks. Because properties in this network are smaller, acquisitions and easements adjacent to existing conserved lands should also be prioritized for conservation action to avoid the creation of small isolated patches in the network. Properties that are only in the transaction-efficient network are generally larger and for many likely have existing economic uses such as timber extraction or ranching. These properties could be good options for incentivizing conservation-compatible management, implementing Other Effective Area-based Conservation Measures (OECMs), or for voluntary conservation easements.

To achieve its ambitious goal within its rapidly approaching deadline, 30×30 will need to be implemented across all regions, by a variety of organizations with different capacities, goals, and geographic focuses, through a mix of private land protection, easements, changes to public land management, incentives, OECMs, and other pathways (CNRA, 2022). Implementation on private land will likely need to include properties with a variety of characteristics, indicative of the various networks we identified here: large remote properties that expand the protected area network; smaller properties that are dense in conservation values but are also expensive and at risk of development; properties that enhance equitable access to nature. All will be necessary. And the framework we presented can inform how each such transaction can be built towards the ultimate goal of a representative network that also provides multiple societal benefits (Figure 4).

4.6 | Budget required

To protect all habitats statewide at 30% through private land acquisition, we estimate between \$5.84 billion to \$19.97 billion dollars will be needed. These estimates are based solely on land values assuming fee acquisition is the only conservation action available to achieve 30×30 targets. However, there are many pathways to 30×30 implementation beyond acquisition of fee title, so our cost estimates of implementation could be biased upwards. For example, retiring extractive uses and increasing the durability of protection and management for biodiversity on public, multiple-use lands that are currently not being counted towards this effort could advance 30×30 objectives without additional land acquisition costs. Another pathway, conservation easements, may be a more cost-effective conservation tool than acquisition as they typically have significantly lower upfront costs than a full acquisition (California Rangeland Trust, 2020; Main et al., 1999; Schöttker & Santos, 2019) as well as lower land management costs. Even just considering private land acquisition, the actual cost of implementation is difficult to predict due to a number of factors that lie beyond the scope of this analysis. We only estimate cost based on land value, but in reality, each transaction will have additional costs associated with the transfer of ownership, land stewardship, recreational access development, biodiversity management, and management for climate resilience. Therefore, even our highest cost estimate (over \$19 billion for the area-efficient network) may be conservative.

5 | CAVEATS AND ASSUMPTIONS

5.1 | Conserved lands

A major decision in planning for and implementing 30×30 is determining "what counts" as protected. We took an inclusive approach to defining what is already protected to better align what counts as protected today with conservation actions that will count for 30×30 moving forward. For example, because easements will be an important tool for private landowners to meaningfully contribute to the 30×30, we erred on the side of inclusion for existing easements even though biodiversity objectives, management requirements, and allowed alternative land uses can be highly variable and were not well documented. Similarly, we included state parks and some lands protected through designations (e.g., ACEC) because both of these are likely critical tools in this accelerated and ambitious goal moving forward. This resulted in higher estimates of currently conserved lands than what the California Natural Resources Agency (2022) is counting, higher estimates of the percentage of each habitat type that is currently conserved, and therefore a conservative estimate of the remaining protection needed and associated budget.

5.2 | Property size

We implemented a minimum planning unit size for analytical feasibility with the assumption that both meaningful conservation action for biodiversity and feasible implementation in the next 6 years will require larger properties and fewer transactions. However, smaller properties will be an important component of the key objective of enhancing access to nature, particularly in urban landscapes.

5.3 | Planning for meaningful biodiversity protection

We applied targets of 30% per coarse habitat type statewide as a starting place, however, targets should be applied per finer-scale habitat and per ecoregion (Groves et al., 2002; Huber et al., 2010) and include fine-filter species level targets. Ecoregional stratification would ensure redundancy of habitat protection across climatic gradients, genotypic and phenotypic variation, and therefore would lead to a network of protected areas more resilient to climate change. It may also offset some of the network differences where efficiency factors may have limited or prioritized inclusion in certain regions. Using a finer classification would ensure more comprehensive representation of habitat types and additionally adding in fine-filter species level targets would ensure that rare and under-protected species are represented in this network. Even with these additions, 30% protection targets will not be sufficient for habitats that have historically been converted. All of these refinements increase the acreage so the networks and associated budgets should be treated as a minimum starting point for meaningful conservation action.

5.4 | Planning for meaningful climate change mitigation

We used carbon storage as a surrogate for climate change mitigation potential. However, this is a limited measure because carbon storage represents a single snapshot in time of carbon on the landscape, but in reality, carbon is dynamic and can increase or decrease with changes to management, land use, climate change, and fire (Sleeter et al., 2019). Also, natural climate solution pathways such as afforestation or agroforestry may have patterns of climate mitigation potential that differ from patterns of current carbon storage and are not evaluated here. Appendix S7 further discusses some of the assumptions and limitations of this analysis.

5.4.1 | Concluding remarks

In this paper, we propose an analytical framework for designing an effective and efficient implementation of 30×30. This framework centers around habitat representation, network design, explicit consideration of efficiency, flexibility, and inclusivity in implementation, and estimate of sufficient budget needed for implementation. We apply this approach to the state of California and use Zonation to identify efficient networks that close the gap in representation of major habitats in the protected area network and that additionally protect places important for biodiversity or climate change mitigation. We find that California could meet its 30×30 goals through private land acquisition for as little as $5.84 billion, with as few as 364 transactions, or with 2.18 million additional conserved hectares. Our findings indicate that network geography is more sensitive to type of efficiency than it is to the chosen planning objective. We show that a single design is limiting because there will always be trade-offs among types of efficiency, inclusivity across regions and implementing actors, and conservation benefits achieved. A better understanding of the kinds of trade-offs measured in this paper will be critical for designing and implementing California's 30×30 effort. As a global environmental leader, the state of California has an opportunity to model a design approach that can inform programs elsewhere in the United States and internationally. Further, 30×30 is just one milestone on a path towards the 50% protection levels needed to truly stem the biodiversity crisis (Bhola et al., 2021; Dinerstein et al., 2019; Wilson, 2016). Reaching these ambitious protection levels will require a long-term planning effort grounded in rigorous estimates of the public benefit of acquiring private lands and an understanding of the trade-offs with other conservation strategies.

AUTHOR CONTRIBUTIONS

CS, DC, and BF developed the analysis and interpreted the results. CS, BF, SM, and DC wrote the paper. CN developed high-resolution cost data for this analysis. CS developed the figures.

ACKNOWLEDGMENTS

We appreciate the insightful feedback on this analysis and interpretation from our Science and External Affairs colleagues at the Nature Conservancy, California. We express our gratitude to GreenInfo Network, in particular Jayita Bhojwani and Dan Rademacher, for their partnership in the development of the property database used in this analysis.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, CS, subject to limitations on proprietary data that was used in the research.

ORCID

Carrie A. Schloss https://orcid.org/0000-0003-3060-8650
D. Richard Cameron https://orcid.org/0000-0001-7750-9049

REFERENCES

Adams, V. M., Pressey, R. L., & Stoeckl, N. (2012). Estimating land and conservation management costs: The first step in designing a stewardship program for the Northern Territory. *Biological Conservation*, *148*(1), 44–53.

Ando, A., Camm, J., Polasky, S., & Solow, A. (1998). Species distributions, land values, and efficient conservation. *Science*, *279*(5359), 2126–2128.

Ball, I., Possingham, H., & Watts, M. (2011). Marxan version 2.4.3. Marine reserve design via annealing. https://marxansolutions.org/software/

Bateman, B. L., Feng, M. L. E., Grand, J., Taylor, L., Wu, J. X., Saunders, S. P., & Wilsey, C. (2023). Where, who, and what counts under area-based conservation targets: A framework for identifying opportunities that benefit biodiversity, climate mitigation, and human communities. *bioRxiv*. [Preprint]. https://doi.org/10.1101/2023.03.24.534176

Bhola, N., Klimmek, H., Kingston, N., Burgess, N. D., van Soesbergen, A., Corrigan, C., Harrison, J., & Kok, M. T. (2021). Perspectives on area-based conservation and its meaning for future biodiversity policy. *Conservation Biology*, *35*(1), 168–178.

Bode, M., Wilson, K. A., Brooks, T. M., Turner, W. R., Mittermeier, R. A., McBride, M. F., Underwood, E. C., & Possingham, H. P. (2008). Cost-effective global conservation spending is robust to taxonomic group. *Proceedings of the National Academy of Sciences*, *105*(17), 6498–6501.

California Department of Forestry and Fire Protection (CAL FIRE). (2015). FVEG. https://frap.fire.ca.gov/mapping/gis-data/

California Natural Resources Agency (CNRA). (2022). Pathways to 30 × 30: Accelerating conservation of California's nature.

California Rangeland Trust. (2020). Frequently asked questions. https://rangelandtrust.org/frequently-asked-questions/

Cameron, D. R., Schloss, C. A., Theobald, D. M., & Morrison, S. A. (2022). A framework to select strategies for conserving and restoring habitat connectivity in complex landscapes. *Conservation Science and Practice*, *4*(6), e12698.

Carroll, C., Noss, R. F., & Stein, B. A. (2022). US conservation atlas needs biodiversity data. *Science*, *376*(6589), 144–145.

Carroll, C., & Ray, J. C. (2021). Maximizing the effectiveness of national commitments to protected area expansion for conserving biodiversity and ecosystem carbon under climate change. *Global Change Biology*, *27*(15), 3395–3414.

Chan, K. M. A., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. *PLoS Biology*, *4*(11), e379.

Conservation Science Partners (CSP). (2019). Methods and approach used to estimate the loss and fragmentation of natural lands in the conterminous U.S. from 2001 to 2017.

Convention on Biological Diversity (CBD). (2022). Kunming-Montreal global biodiversity framework. Secretariat of the Convention on Biological Diversity.

Costello, C., & Polasky, S. (2004). Dynamic reserve site selection. *Resource and Energy Economics*, *26*(2), 157–174.

Crossley, M. S., Meier, A. R., Baldwin, E. M., Berry, L. L., Crenshaw, L. C., Hartman, G. L., Lagos-Kutz, D., Nichols, D. H., Patel, K., Varriano, S., Snyder, W. E., & Moran, M. D. (2020). No net insect abundance and diversity declines across US long term ecological research sites. *Nature Ecology & Evolution*, *4*(10), 1368–1376.

Di Minin, E., Veach, V., Lehtomäki, J., Montesino Pouzols, F., & Moilanen, A. (2014). A quick introduction to zonation. https://core.ac.uk/download/pdf/33733621.pdf

Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., Cmayorga, J., Olson, D., Asner, G. P., Baillie, J. E. M., Burgess, N. D., Burkart, K., Noss, R. F., Zhang, Y. P., Baccini, A., Birch, T., Hahn, N., & Wikramanayake, E. (2019). A global deal for nature: Guiding principles, milestones, and targets. *Science Advances*, *5*(4), eaaw2869.

Dreiss, L. M., Lacey, L. M., Weber, T. C., Delach, A., Niederman, T. E., & Malcom, J. W. (2022). Targeting current species ranges and carbon stocks fails to conserve biodiversity in a changing climate: Opportunities to support climate adaptation under 30 × 30. *Environmental Research Letters*, *17*(2), 024033.

Dreiss, L. M., & Malcom, J. W. (2022). Identifying key federal, state, and private lands strategies for achieving 30 × 30 in the United States. *Conservation Letters*, *15*(1), e12849.

Dudley, N. (2008). *Guidelines for applying protected area management categories*. IUCN.

Gallo, J. A., Lombard, A. T., Cowling, R. M., Greene, R., & Davis, F. W. (2023). Meeting human and biodiversity needs for 30 × 30 and beyond with an iterative land allocation framework and tool. *Land*, *12*(1), 254.

GreenInfo Network. (2022a). California conservation easement database (CCED). www.calands.org

GreenInfo Network. (2022b). California protected areas database (CPAD). www.calands.org

Groves, C., & Game, E. T. (2016). *Conservation planning: Informed decisions for a healthier planet*. Roberts Publishers.

Groves, C. R. (2003). *Drafting a conservation blueprint: A practitioner's guide to planning for biodiversity*. Island Press.

Groves, C. R., Jensen, D. B., Valutis, L. L., Redford, K. H., Shaffer, M. L., Scott, J. M., Baumgartner, J. V., Higgins, J. V., Beck, M. W., & Anderson, M. G. (2002). Planning for biodiversity conservation: Putting conservation science into practice. *Bioscience*, *52*, 499–512.

Halpin, P. N. (1997). Global climate change and natural-area protection: Management responses and research directions. *Ecological Applications*, *7*(3), 828–843.

Hamilton, H., Smyth, R. L., Young, B. E., Howard, T. G., Tracey, C., Breyer, S., Cameron, D. R., Chazal, A., Conley, A. K., Frye, C., & Schloss, C. (2022). Increasing taxonomic diversity and spatial resolution clarifies opportunities for protecting US imperiled species. *Ecological Applications*, *32*(3), e2534.

Howard, J. K., Fesenmyer, K. A., Grantham, T. E., Viers, J. H., Ode, P. R., Moyle, P. B., Kupferburg, S. J., Furnish, J. L., Rehn, A., Slusark, J., & Wright, A. N. (2018). A freshwater conservation blueprint for California: Prioritizing watersheds for freshwater biodiversity. *Freshwater Science*, *37*(2), 417–431.

Huber, P. R., Greco, S. E., & Thorne, J. H. (2010). Spatial scale effects on conservation network design: Trade-offs and omissions in regional versus local scale planning. *Landscape Ecology*, *25*, 683–695.

Hunter, M. L., Jr., Jacobson, G. L., Jr., & Webb, T., III. (1988). Paleoecology and the coarse-filter approach to maintaining biological diversity. *Conservation Biology*, *2*(4), 375–385.

IPCC. (2023). Sections. In Core Writing Team, H. Lee, & J. Romero (Eds.), *Climate change 2023: Synthesis report. Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental panel on climate change* (pp. 35–115). IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647

Jetz, W., McGowan, J., Rinnan, D. S., Possingham, H. P., Visconti, P., O'Donnell, B., & Londoño-Murcia, M. C. (2022). Include biodiversity representation indicators in area-based conservation targets. *Nature Ecology & Evolution*, *6*(2), 123–126.

Kling, M. M., Mishler, B. D., Thornhill, A. H., Baldwin, B. G., & Ackerly, D. D. (2019). Facets of phylodiversity: Evolutionary diversification, divergence and survival as conservation targets. *Philosophical Transactions of the Royal Society B*, *374*(1763), 20170397.

Kreitler, J., Schloss, C. A., Soong, O., Hannah, L., & Davis, F. W. (2015). Conservation planning for offsetting the impacts of development: A case study of biodiversity and renewable energy in the Mojave Desert. *PLoS ONE*, *10*(11), e0140226.

Kukkala, A. S., & Moilanen, A. (2013). Core concepts of spatial prioritisation in systematic conservation planning. *Biological Reviews*, *88*(2), 443–464.

Laliberte, A. S., & Ripple, W. J. (2004). Range contractions of north American carnivores and ungulates. *BioScience*, *54*(2), 123–138.

Main, M. B., Roka, F. M., & Noss, R. F. (1999). Evaluating costs of conservation. *Conservation Biology*, *13*(6), 1262–1272.

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature*, *405*(6783), 243–253.

Maron, M., Rhodes, J. R., & Gibbons, P. (2013). Calculating the benefit of conservation actions. *Conservation Letters*, *6*(5), 359–367.

Moilanen, A. (2007). Landscape zonation, benefit functions and target-based planning: Unifying reserve selection strategies. *Biological Conservation*, *134*(4), 571–579.

Moilanen, A., Pouzols, F. M., Meller, L., Veach, V., Arponen, A., Leppänen, J., & Kujala, H. (2014). *Zonation version 4 user manual*. Biodiversity Conservation Informatics Group, University.

Murdoch, W., Polasky, S., Wilson, K. A., Possingham, H. P., Kareiva, P., & Shaw, R. (2007). Maximizing return on investment in conservation. *Biological Conservation*, *139*(3–4), 375–388.

Muths, E. (2012). *The state of amphibians in the United States*. U.S. Department of the Interior. U.S. Geological Survey, Amphibian Research and Monitoring Initiative.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853–858.

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., & Rouget, M. (2006). Integrating economic costs into conservation planning. *Trends in Ecology & Evolution*, *21*(12), 681–687.

Nelson, E., Polasky, S., Lewis, D. J., Plantinga, A. J., Lonsdorf, E., White, D., Bael, D., & Lawler, J. J. (2008). Efficiency of incentives to jointly increase carbon sequestration and species conservation on a landscape. *Proceedings of the National Academy of Sciences*, *105*(28), 9471–9476.

Nolte, C. (2020). High-resolution land value maps reveal underestimation of conservation costs in the United States. *Proceedings of the National Academy of Sciences*, *117*(47), 29577–29583.

Noss, R. F. (1987). From plant communities to landscapes in conservation inventories: A look at the nature conservancy (USA). *Biological Conservation*, *41*(1), 11–37.

Olson, D. M., & Dinerstein, E. (1998). The global 200: A representation approach to conserving the Earth's most biologically valuable ecoregions. *Conservation Biology*, *12*(3), 502–515.

Oshun, M. I., & Grantham, T. E. (2023). Leveraging species richness and ecological condition indices to guide systematic conservation planning. *Journal of Environmental Management*, *341*, 117970.

Parker, S. (2012). Small reserves can successfully preserve rare plants despite management challenges. *Natural Areas Journal*, *32*(4), 403–411.

Polasky, S. (2008). Why conservation planning needs socioeconomic data. *Proceedings of the National Academy of Sciences*, *105*(18), 6505–6506.

Polasky, S., Camm, J. D., & Garber-Yonts, B. (2001). Selecting biological reserves cost-effectively: An application to terrestrial vertebrate conservation in Oregon. *Land Economics*, *77*(1), 68–78.

Polasky, S., Johnson, K., Keeler, B., Kovacs, K., Nelson, E., Pennington, D., Plantinga, A. J., & Withey, J. (2012). Are investments to promote biodiversity conservation and ecosystem services aligned? *Oxford Review of Economic Policy*, *28*(1), 139–163.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., III, Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2), 32.

Rosenberg, K. V., Dokter, A. M., Blancher, P. J., Sauer, J. R., Smith, A. C., Smith, P. A., Stanton, J. C., Panjabi, A., Helft, L., Parr, M., & Marra, P. P. (2019). Decline of the north American avifauna. *Science*, *366*(6461), 120–124.

Schöttker, O., & Santos, M. J. (2019). Easement or public land? An economic analysis of different ownership modes for nature conservation measures in California. *Conservation Letters*, *12*(6), e12647.

Simmons, B. A., Nolte, C., & McGowan, J. (2021). Delivering on Biden's 2030 conservation commitment. *bioRxiv* [preprint]. https://doi.org/10.1101/2021.02.28.433244

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

State of California. (2020). Executive Order N-82-20. https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-.pdf

Stewart, J. A. E., Thorne, J. H., Gogol-Prokurat, M., & Osborn, S. D. (2016). *A climate change vulnerability assessment for twenty California mammal taxa*. California Department of Fish and Wildlife. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=135825&inline

Stralberg, D., Berteaux, D., Drever, C. R., Drever, M., Naujokaitis-Lewis, I., Schmiegelow, F. K., & Tremblay, J. A. (2019). Conservation planning for boreal birds in a changing climate: A framework for action. *Avian Conservation & Ecology*, *14*(1), 13.

U.S. Geological Survey (USGS) Gap Analysis Project (GAP). (2020). *Protected Areas Database of the United States (PAD-US)*. U.S. Geological Survey. https://doi.org/10.5066/P9Q9LQ4B

Veloz, S. D., & Jongsomjit, D. (2012). California bird species richness index from modeling bird distribution responses to climate change. *Point Blue Conservation Science* http://climate.calcommons.org/dataset/14

Venegas Li, R., Grantham, H., Rainey, H., Diment, A., Tizard, R., & Watson, J. E. (2023). An operational methodology to identify critical ecosystem areas to help nations achieve the Kunming-Montreal global biodiversity framework. *bioRxiv*. https://doi.org/10.1101/2023.05.03.539215

Wilson, E. O. (2016). *Half-earth: Our planet's fight for life*. WW Norton & Company.

Wright, A. N., Hijmans, R. J., Schwartz, M. W., & Shaffer, H. B. (2013). *California amphibian and reptile species of future concern: Conservation and climate change*. California Department of Fish and Wildlife. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=83972

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Schloss, C. A., Cameron, D. R., Franklin, B., Nolte, C., & Morrison, S. A. (2024). An approach to designing efficient implementation of 30×30 terrestrial conservation commitments. *Conservation Science and Practice*, *6*(10), e13232. https://doi.org/10.1111/csp2.13232