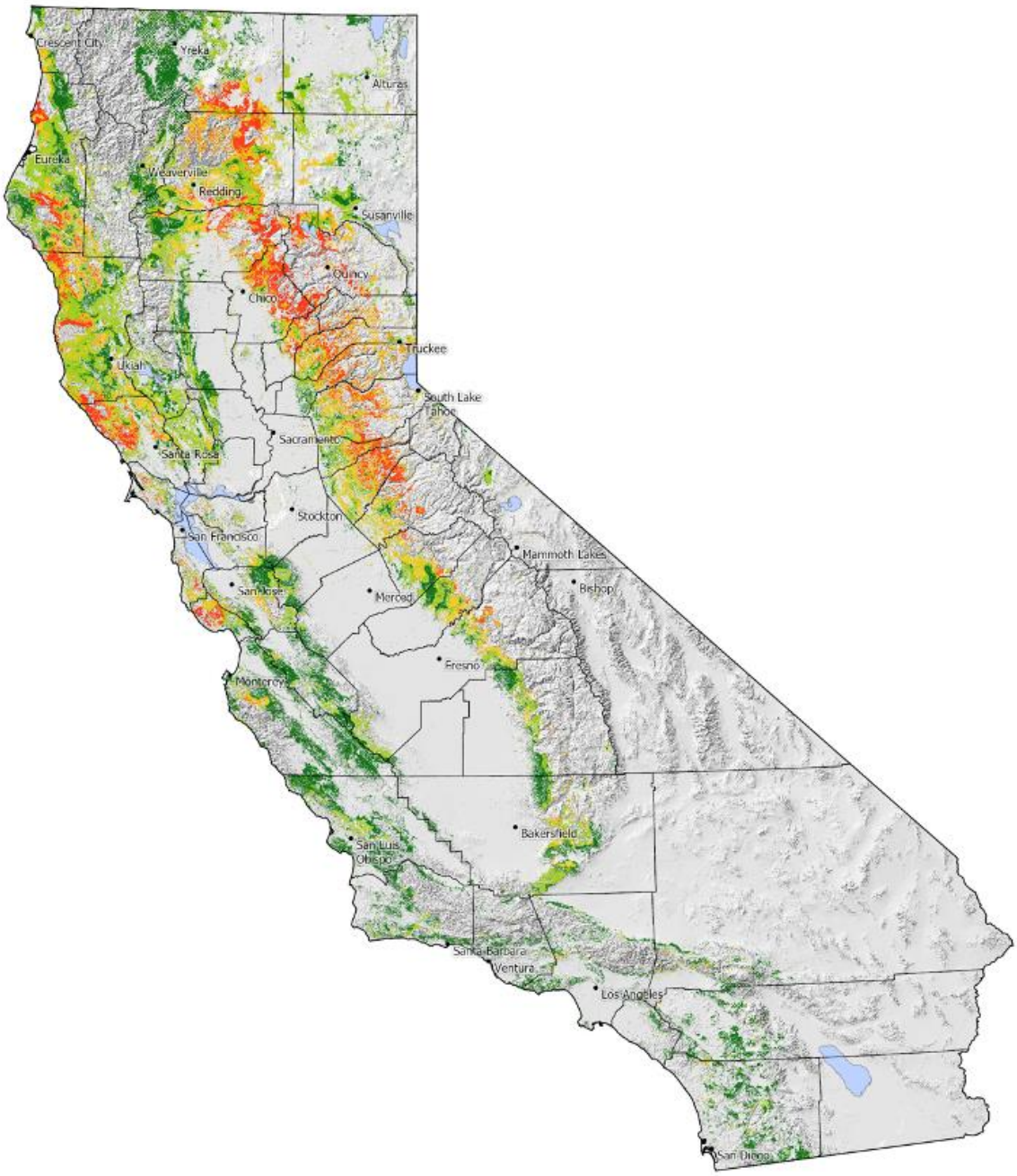
Forest Legacy Assessment of Need

Prioritization of Opportunities to Conserve Environmentally Significant Forests within California's Forest Legacy Area

2020



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Prepared by Pacific Forest Trust for CAL FIRE per contract 9CA04749
GIS analysis by FRAP

Purpose and Need for this Addendum and Update to the Assessment of Need

The federal Forest Legacy Program (FLP) requires the state to evaluate current forests, forest uses, and the trends and forces causing conversion of environmentally significant forests to non-forest uses. With the update to the Cooperative Forestry Assistance Act contained in the 2008 Farm Bill, the preferred approach to assessing these issues is through a state's Forest Action Plan, as it provides a comprehensive overview of a state's forests and stewardship priorities.

The FLP guidelines also require identification of:

- eligibility criteria for Forest Legacy Areas;
- specific Forest Legacy Areas for designation;
- specific goals and objectives for the program; and
- the process used by the lead agency to evaluate and prioritize projects.

This document addresses these requirements, and when used in conjunction with the California Forest Action Plan, satisfies the Forest Legacy program requirements for an update to the Assessment of Need.

Since California's original Assessment of Need (AON), last updated in the year 2000, the state's forests have changed significantly, and continue to change at an unprecedented rate due to drought, climate change, insect outbreaks, fire, and competing land uses. Technologies and the efforts to refine scientific assessments of these changes are evolving rapidly as well. The California Department of Forestry and Fire Protection (CAL FIRE, or the Department) anticipates updating this document as necessary to incorporate new information, substantially changed circumstances, or new policy direction.

Identifying the following aspects of the Forest Legacy Implementation Guidelines-

a. Location of each geographic area on a map and a written description of the proposed FLA boundary

f. Identification of the governmental entity or entities that may hold lands or interests in lands (State grant option) or may be assigned management responsibilities for the lands and interests in lands enrolled in the FLP (Federal option)

California's Forest Legacy Areas (FLAs) remain unchanged from the AON update approved in 2000. The FLA boundaries are defined by 34 participating counties that span the state (Figure 1). Within each FLA, we also show the amount of privately-owned non-industrial forested land and major vegetation types (Figures 2 and 3) to provide a foundation for internal prioritization of Forest Legacy and other state-level forest health projects.

While any forested area in any FLA is a candidate for Forest Legacy projects, we took the further step of mapping and ranking FLP project candidate areas based upon the relative values of their environmental and social assets. Developed in partnership through a series of public meetings with the Forest Stewardship Coordinating Committee (FSCC), we used a set of criteria to rank areas at a sub-FLA level, based upon their relative importance with respect to the objectives of the program (see Figure on page 28). These are described and displayed in maps in sections throughout this document, and fulfill the requirements listed on page 20 (under Identification of Forest Legacy Areas) in the Forest Legacy Program Guidelines (USFS, 2017).

Because California has a number of other programs that address forest conservation and restoration and may also use this prioritization to inform those programs, we include the prioritization of conservation opportunities for all private forest in the state, not just those in the FLAs. This does not expand the current FLAs, but does make the prioritization useful for other purposes.

There has been no change in which governmental entity may hold lands or interests in lands or may be assigned management responsibilities for the lands and interest in lands enrolled in the FLP. CAL FIRE will continue to consider itself the sole holder of interests in lands funded from the Federal Forest Legacy Program and will continue to allow assignment of monitoring responsibilities to Land Trusts or other similar entities where appropriate.

Major Changes Since the Last Assessment of Need

The original AON was prepared in 1995 and updated in 2000. California has changed in many ways since then, notably:

Population Increase

When the original AON was prepared in 1995 there were 31.5 million people in California, and there were 33.6 million people when the AON was updated in 2000. There are now an estimated 40 million people in the state, all reliant on forests for water supply, climate benefits, open space and aesthetics, and other ecosystem services.

Climate Change

In 1995 and 2000 there was increasing awareness of climate change and its myriad impacts, but it was not a major element of policy and management. In 2020, however, climate change is a clear driver of the state's longer and more intense fire seasons, and is causing changes in species distribution and shifts in vegetative communities. Climate change is a significant resource management challenge and policy driver; California has robust climate policy addressing many aspects of land use and the economy, and this is likely to continue to be an area of quickly evolving policy and scientific understanding.

Forest Structure

The last two decades have seen a much greater recognition, in both research and policy, that past forest management and ongoing fire suppression have led to conditions that are unlike historical forest conditions. California's forests have a generally more homogeneous structure and many crowded stands with too many small trees and too few large trees. Discussed further below, this simplified structure and excessive density creates heightened risks of fire, insect infestation, and disease – and lessens resilience to disturbance – across much of California's timberland. In addition to having implications for watershed health, such changes in forest structure have diminished habitat quality and increased threats to many fish and wildlife species, including ones listed as threatened or endangered.

Increased Financial Expectations Challenge the Maintenance of Large, Intact Landscapes

Since 1995, short-term financial pressures on forestland owners have increased, as the expectations for financial returns is now compared to other financial opportunities with high rates – and short time frames – of return. In addition, in many places real estate value has increase more quickly than timber value. This leads to large forest ownerships being constantly reviewed for their "highest and best" economic use, which is often sale for real estate development values or, in some cases, intensified short-term management. As we increasingly recognize the need to restore more fire- and climate- resilient forest structure – and include expanded use of prescribed fire in the tools to achieve healthy forest conditions – maintaining large, intact working landscapes is a key challenge.

California Forest Distribution

Nearly one-third of California is covered by various types of forest[1] (31.9 million of approximately 100 million acres), with privately-owned forests covering about 13.8 million of these acres. Area covered by timberland – forests capable of being managed for timber production – cover about 16.6 million acres, with 7.25 million of that owned by private interests. See Figure 2 for the distribution of private forestlands in California and Figure 3 for the major vegetation types. Note that the California Forest Action Plan contains a much more extensive discussion of forest characteristics, uses, trends, and forces causing conversion and other changes. Further, CAL FIRE's Fire and Resource Assessment Program (FRAP) maintains a statewide assessment (see https://frap.fire.ca.gov/assessment) that links together state requirements for natural resource inventories and strategies in response to the federal government's desire to rely more heavily on these state programs in determining priorities for funding.

[1] In this context "forest" includes all land with at least 10% tree canopy cover.

Figure 1. California's Forest Legacy Areas (FLAs).

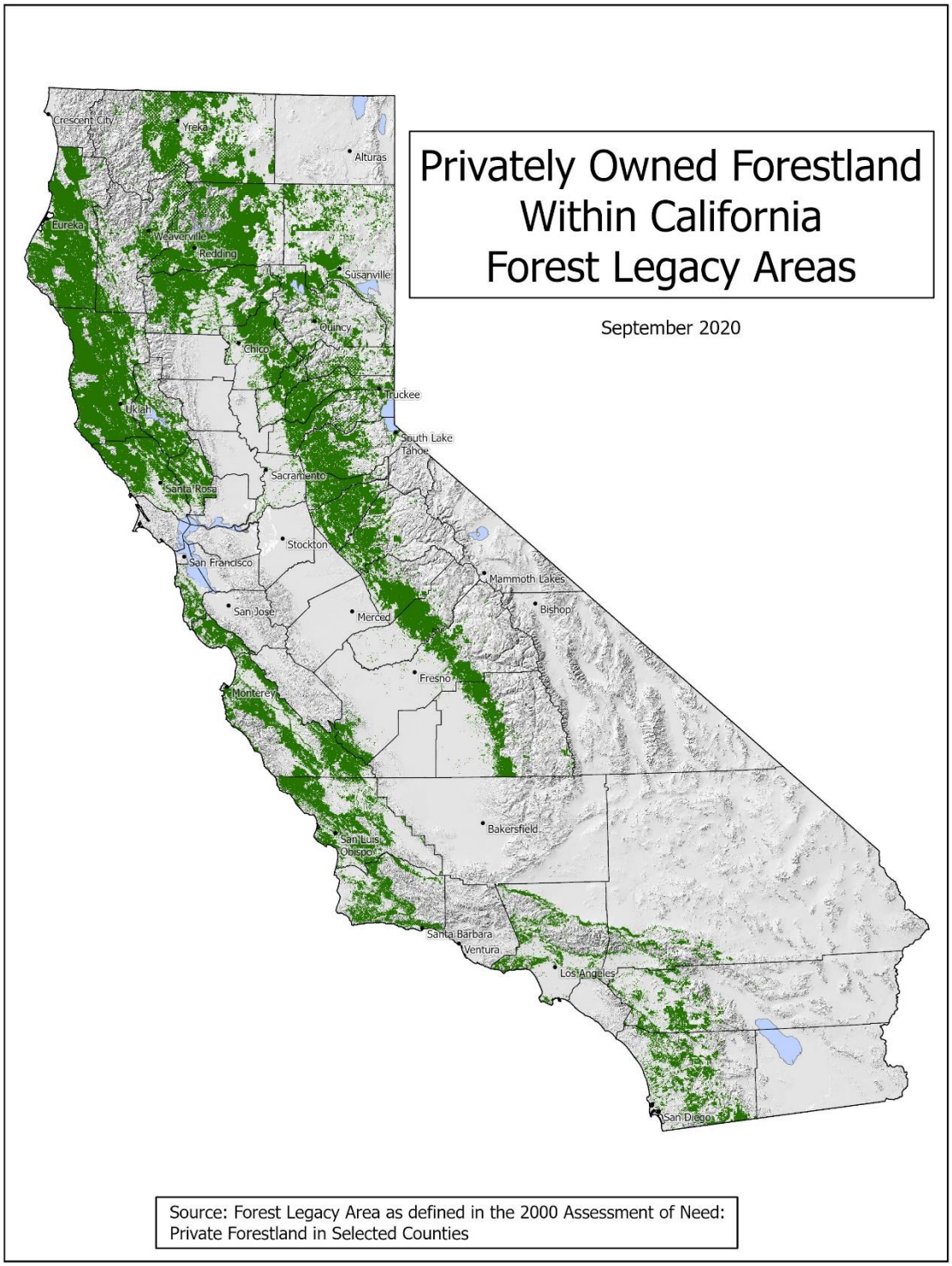


Figure 2. Privately-Owned Forestland within Forest Legacy Areas.

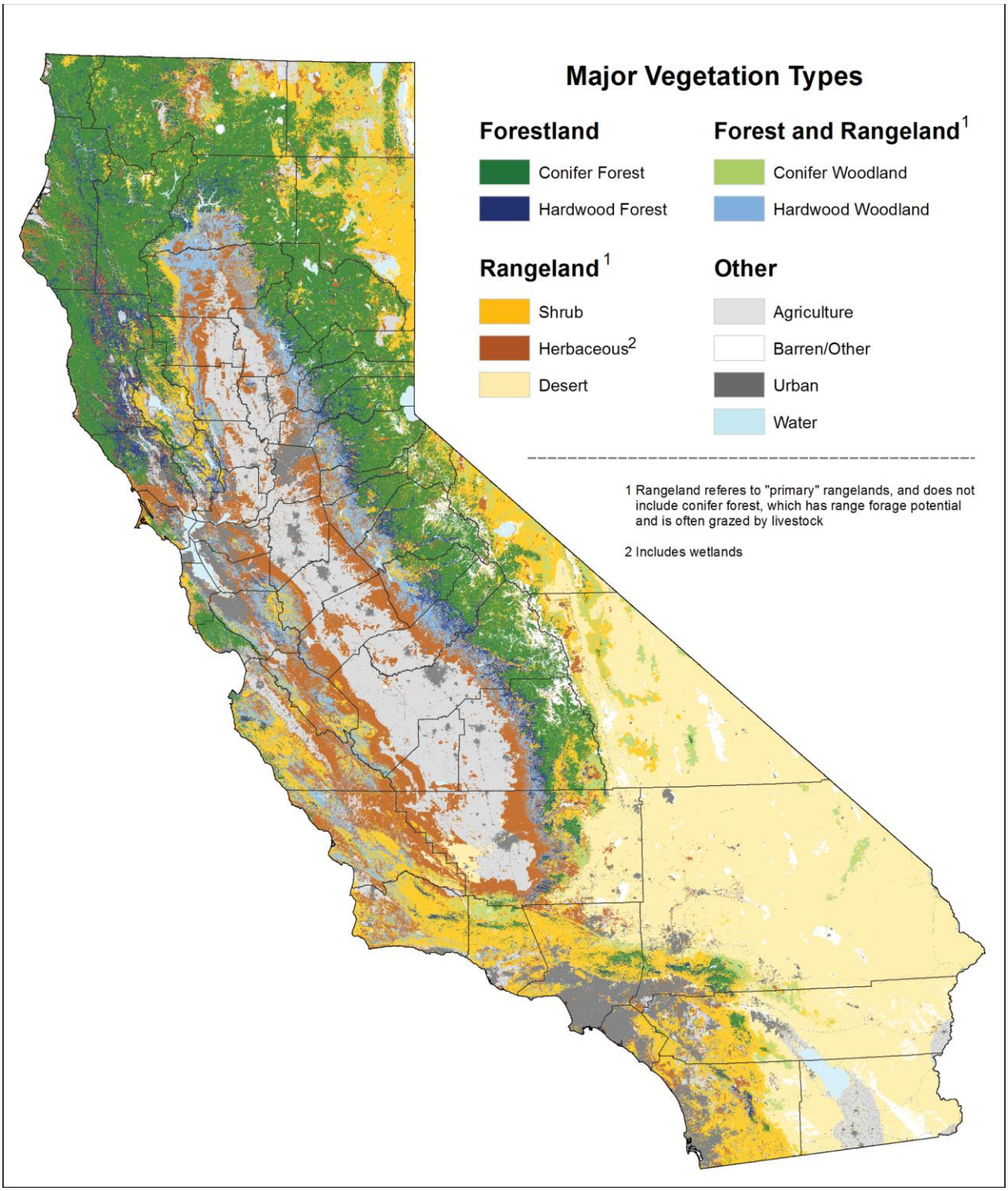


Figure 3. Distribution of Major Vegetation Types. Vegetation Type mapping is based on the California Department of Fish and Wildlife's Wildlife Habitat Relationship (WHR) system. GIS layer was compiled by FRAP (2015) from multiple sources. Note that "woodland" types generally have less canopy density than "forest" types, but still over the 10% canopy standard for inclusion in the Forest Legacy Area.

Forest Structure

The structure and composition of California's forests have been dramatically altered since the mid-1800s with the arrival of European settlers. In addition to large areas of forestland permanently converted to urban and agricultural uses, past management and fire suppression have led to forest conditions that are generally well outside the historic natural range of variability. The 2017 U.S. Forest Service General Technical Report 256, *Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests*,[2] provides excellent perspective on the forests that dominate the eastern half of the state. From the document's summary:

> There is strong consensus among published studies that, on average, modern YPMC [yellow pine and mixed conifer] stands have much higher densities dominated by smaller trees (often of shade-tolerant species), much longer fire-return intervals, and less area burned across the landscape compared to reference YPMC forests.
> …
> The past 150 years have seen extensive changes to assessment area YPMC forests, which experienced large-scale logging and subsequent, nearly ubiquitous fire exclusion that have dramatically altered contemporary forest structure and ecological processes.
> …
> Models and present-day reference landscapes suggest that roughly 50 percent of the presettlement landscape would have been in an old-growth condition, but this old-growth condition included both open stands of yellow pine and dry mixed conifer, and more closed-canopy stands of moist mixed conifer. Thus, stand structure within YPMC stands was likely highly variable, but in general, stands were characterized by relatively low tree densities and large tree sizes.
> …
> The heterogeneity of presettlement landscapes in YPMC forests has been simplified over the past 150 years, primarily by logging and fire exclusion, which have led to an increase in small-tree density and a decrease in large-tree density relative to the natural range of variation (NRV).
> …
> Most of this increase is in trees <60 cm [less than 24 inches] diameter at breast height (d.b.h.). Corresponding changes in forest and understory structure from the presettlement era include a decrease in the average tree size (d.b.h.) by 25 to 40 percent; an increase in canopy cover by ~25 percent; a near-complete loss of fine-scale canopy gaps; increases in snag density, coarse woody debris, litter, and duff depth; and surface fuel volume and continuity. These changes in stand structure have caused changes in other ecosystem processes. For instance, insect and pathogen activity has

[2] Safford, Hugh D.; Stevens, Jens T. 2017. Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 229 p. See https://www.fs.usda.gov/treesearch/pubs/55393

probably increased with stand density (although pre-settlement information on this is sparse), while litter and duff accumulation can increase nutrients leaching to surface and ground water, and, combined with increased small-tree density, increase vulnerability to high-severity fire.

While the Forest Service has not yet completed a similar assessment for California's coastal forests, past management patterns and fire suppression have contributed to a similarly simplified forest structure.

Goals and Objectives for Forest Legacy and Related Efforts in California

Identifying the following aspects of the Forest Legacy Implementation Guidelines

d. The conservation goals or objectives in each FLA

e. List of public benefits that will be derived from establishing each FLA

The conservation goals of the Forest Legacy program, and in each FLA, are to prevent conversion of environmentally significant forests, maintain traditional uses (including forest management), and protect and enhance forest values including wildlife habitat, watershed function, carbon sequestration, climate adaptation, and fire resilience, that are consistent with their statutory requirements[3]. California has numerous plans that are relevant to the state's policy goals of conserving and restoring more carbon-rich and climate-resilient forests while aggressively mitigating the risk of catastrophic fire. Notably relevant plans include the:

- Forest Carbon Plan;
- 2017 Scoping Plan Update: The Strategy for Achieving California's 2030 GHG Target;
- Safeguarding California Climate Adaptation Plan;
- State Wildlife Action Plan;
- Natural and Working Lands Climate Change Implementation Plan;
- Executive Order B-55-18, which establishes a goal of carbon neutrality by 2045, calling for the Natural and Working Lands Climate Change Implementation Plan to help meet these targets, and for actions to "support climate adaptation and biodiversity, including protection of the state's water supply, water quality, and native plants and animals;" and the
- California Water Plan.

The established FLAs will continue to facilitate and encourage voluntary efforts by private forestland owners to protect and/or restore the forest landbase, forest health and ecosystem function, water quality and other watershed values, biodiversity, fish and wildlife habitat, listed

[3] See Federal Forest Legacy statute at 16 U.S.C. §2103c and the state FLP statute at PRC §12240

and sensitive species habitat, and opportunities for the production of forest products for the benefit of current and future generations. In some cases, landowners may also choose to benefit the public by protecting other forest resources and traditional uses defined by the State Forest Stewardship Coordinating Committee such as public recreation, cultural resources, or scenic enjoyment.

Consideration of Climate Change in Forest Legacy Project Development and Selection

Climate change is affecting the type and distribution of forests in California, and these changes are accelerating. In many places the historic uses (such as timber harvest) may no longer be viable in the future as conifer forests shift to hardwoods or chaparral. Regeneration harvests may no longer be desirable in certain areas, as these expose more soil to heat and drying, reducing the likelihood of conifer regeneration as in prior years. These changes in habitat also have implications for key ecosystem services such carbon sequestration and water supply – changes in forest type, combined with shifts in precipitation and increases in temperature, will have profound impacts on the timing of runoff and the function of water storage facilities. In general, chaparral, shrub, and hardwood forest types are moving upslope and expanding northwards, sometimes displacing conifer forest types such as red fir, which are moving upslope and north as well.

Better understanding how climate change is likely to occur across the state can help inform land management and conservation decisions. A 2020 analysis by UC Davis, with the California Department of Fish and Wildlife and the USDA El Dorado National Forest, modeled climate refugia – locations that are expected to maintain the same dominant vegetation types at the end of the century – under the 'business as usual' emission scenarios for the two global climate models (wetter [CNRM-CM5] vs. drier [MIROC ESM]).[4] While there is still uncertainty about which of these scenarios is more likely, this analysis highlights where there is agreement between the models.

Figure 4 shows areas of likely climate refugia for each scenario, as well as areas of consensus between the models. Figure 5 shows where there is model agreement that the dominant vegetation is likely to remain stable, as well as areas where the current vegetation is likely to be marginal and very stressed. For this exercise, areas described as refugia have future climates consistent with where 80% of the vegetation type currently occur. The areas described as "stressed" are projected to reflect conditions analogous to the most marginal 5% of current distribution.

The FLP intends to use assessments of future climate conditions to focus project development in areas of high ecological and watershed value, and which are likely to remain climate refugia with relatively stable climate and vegetative communities. This will allow the program to focus

[4] Thorne, James H, Gogol-Prokurat , Melanie; Hill, Sandra; Walsh, Dana; Boynton, Ryan M, and Choe, Hyeyeong. 2020. Vegetation refugia can inform climate-adaptive land management under global warming. Frontiers in Ecology and the Environment. 7pp. See: https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1002/fee.2208

its efforts on maintaining working forest land, restoring forest structure, protecting key ecosystem services, and building resilience to impending climate pressures.

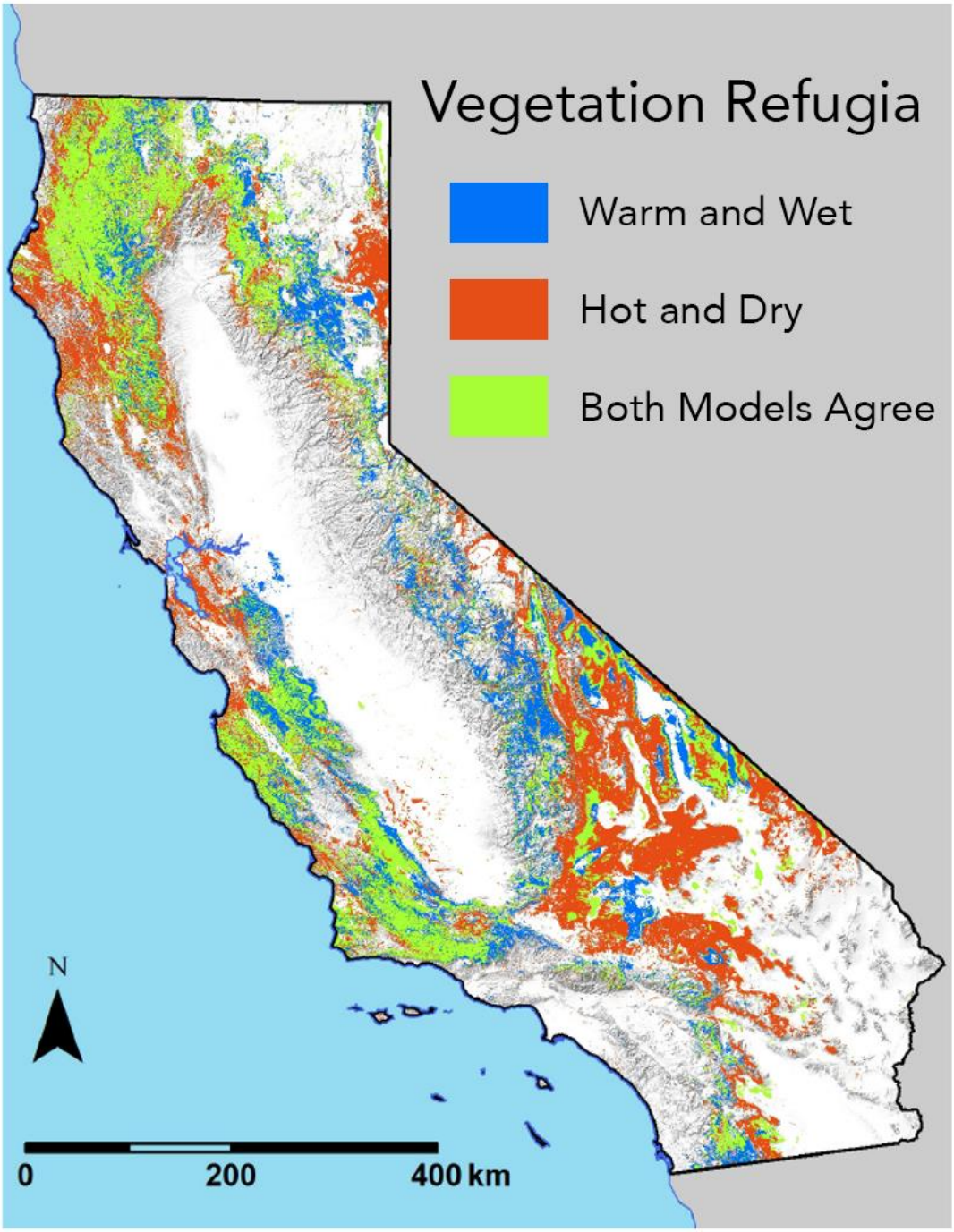


Figure 4. Vegetation refugia by 2070–2099 under wetter (CNRM-CM5) and drier (MIROC-ESM) global climate models (GCMs). Areas in green represent consensus refugia: areas for which the two GCMs agree that suitable climate conditions will be retained for the current vegetation.

Areas in blue or red represent additional lands considered as vegetation refugia by one of the models. Note that the modeling reflects 43 vegetation types across both public and private lands, not just the Forest Legacy Area.

From Thorne et al, 2020

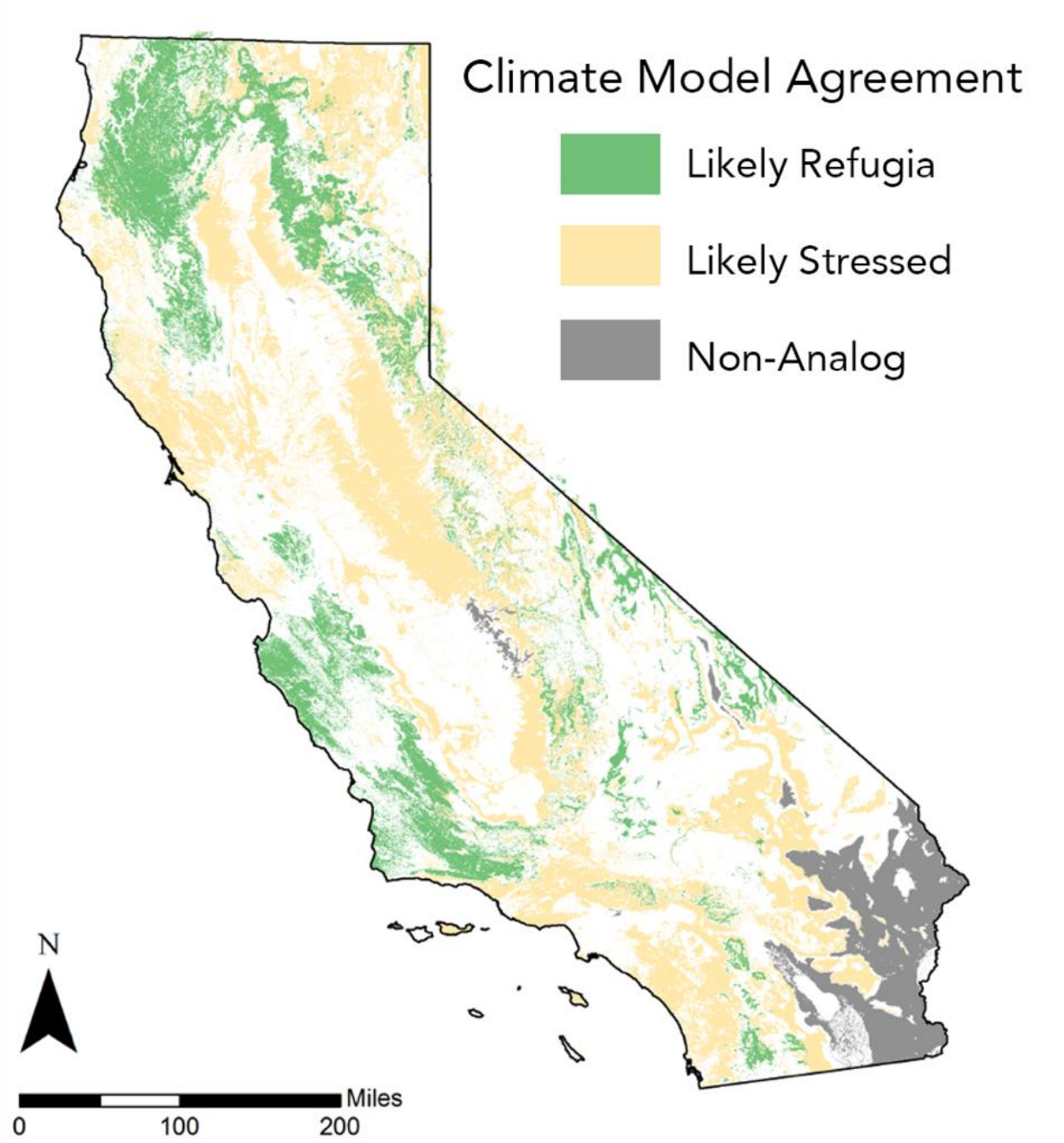


Figure 5. Areas of Agreement between Major Climate Models for Climate Refugia and Climate Stress on Dominant Vegetation in 2070-2099. "Refugia" reflects conditions seen in 80% of present-day distribution. "Stressed" reflects conditions seen in the most marginal 5% of the current distribution. Non-Analog indicates that modeled conditions do not have a present-day corollary in California. Both models – CNRM-CM5, (warmer and wetter) and MIROC ESM, (hotter and drier) – reflect the current "business as usual" emission scenario, RCP8.5. Note that

this modeling reflects 43 vegetation types across both public and private lands, not just the Forest Legacy Area.

Development of the State Forest Action Plan and the Prioritization of the Forest Legacy Area

Identifying the following aspects of the Forest Legacy Implementation Guidelines:

b. Summary of the analysis used to identify the FLA and its consistency with the eligibility criteria.

c. Identification of important environmental values and how they will be protected and conserved

g. Documentation of the public involvement process and analysis of the issues raised.

The FLAs are unchanged in this iteration and therefore were not reanalyzed. However, to better identify opportunities to protect environmentally significant forestland, and to provide for public involvement, the Department consulted with the Forest Stewardship Coordinating Committee (FSCC) through several meetings in 2019 and 2020 to identify key values and attributes to include in this prioritization effort. CAL FIRE staff and the FSCC discussed several ideas on how to move forward with this evaluation, and eventually decided on the process that lead to the analysis presented in this document. Notably, the FSCC decided to explore 16 potential attributes that could be relevant to establishing priorities within California's Forest Legacy Area. The list was narrowed to the eight most relevant and usable criteria then ranked by the FSCC as Low, Medium, or High priority. Those rankings were used to inform the relative weighting of the attributes in the final prioritization map.

Based on those discussions, the following attributes were identified as most important to help the Program meet the goals and objectives outlined above:

- Threat of conversion to non-forest use
- Importance to public water supplies
- Habitat value, especially for threatened and endangered species
- Habitat connectivity
- Site productivity
- Proximity to other conserved lands
- Importance to state water supplies and storage
- Resilience, or vulnerability, to climate change

Other attributes considered but not included were Riparian Areas, Wildfire Hazard, Cannabis Grow Conversions, Forest Type, Forest Pest Mortality, Soil Erosion Potential, Wildland Urban Interface, Number of Potential Collaborators, Nonindustrial Ownership, and Industrial Ownership. While these attributes were considered important, the FSCC decided to limit the span of attributes for consideration to those that were deemed the highest priority. In future iterations of this Assessment, the FSCC agreed that there may be other attributed identified as priorities and conditions change in CA.

From these final eight attributes, the FSCC then evaluated their respective importance through identifying a relative weighting factor to apply to each attribute for the final prioritization process.

The criteria considered are shown in the table below:

Attributes Included in the Priority Landscape Assessment Map[5]		
Attribute Considered	**Rationale**	**Data Source** *See Technical Notes at end of document for more details*
Conversion Threat	A Forest Legacy Program priority, defined here as an increase of housing density from below Wildland Urban Interface (<=1 housing unit per 20 acres) to at or above the WUI density.	The US Environmental Protection Agency Integrated Climate and Land Use Scenarios (ICLUS) model, as developed by FRAP for the 2017 Forest and Rangeland Assessment.
Public Water Supply	Maintaining forest cover and improving management are priorities for protecting public water supplies.	US Forest Service's Forests to Faucets Program, selecting the top-tier of watersheds that provide water to municipalities (IMP >= 60).
Threatened and Endangered Species Habitat (Terrestrial)	Recovery of threatened and endangered species is a state and federal priority.	US Fish and Wildlife Service data of officially designated critical habitat plus the State Wildlife Action Plan (SWAP) Conservation Target vegetation types from the Areas of Conservation Emphasis program (ACE2).
Habitat Connectivity	Providing connections between core habitat areas substantially increases conservation outcomes.	California Department of Fish and Wildlife Area of Conservation Emphasis III (ACEIII), Terrestrial Connectivity Layer (ds2734).
Site Productivity	A goal of the FLP is to maintain historic uses, including sustainable timber harvest from working forests. Higher site productivity suggests potential commercial use and serves as a surrogate for carbon sequestration capacity.	Forest Inventory and Analysis (FIA) data, as processed by Wilson (2015), using standard site classes of 1 through 3 from that GIS layer to represent the highest productivity forestlands in the state.
Proximity to Public or Other Conserved Land	Aggregating conserved and well-managed forests has greater conservation benefits.	Data from the Conserved and Protected Areas (CPAD) and Conservation Easements (CCED) databases, as well as public ownership were used as spatial "centers", from which buffers were extended two miles.
Priority Watersheds for State & Central Valley Water Project Supply	The Central Valley Project and State Water Project supply over 22 million people and most of California's irrigated agriculture.	FRAP 2010 Forest and Rangelands Assessment water storage asset. Watersheds that are ranked as high priority.
Watersheds with Multiple ESA Listed Salmon Present	Recovery of threatened and endangered species is a state and federal priority. Addressed separately from other critical habitat due to extremely broad extent.	Watersheds with at least two listed salmonid species, based on NOAA Fisheries critical habitat designation.

[5] Other attributes considered but not included were Riparian Areas, Wildfire Hazard, Cannabis Grow Conversions, Forest Type, Forest Pest Mortality, Soil Erosion Potential, Wildland Urban Interface, Number of Potential Collaborators, Nonindustrial Ownership, and Industrial Ownership.

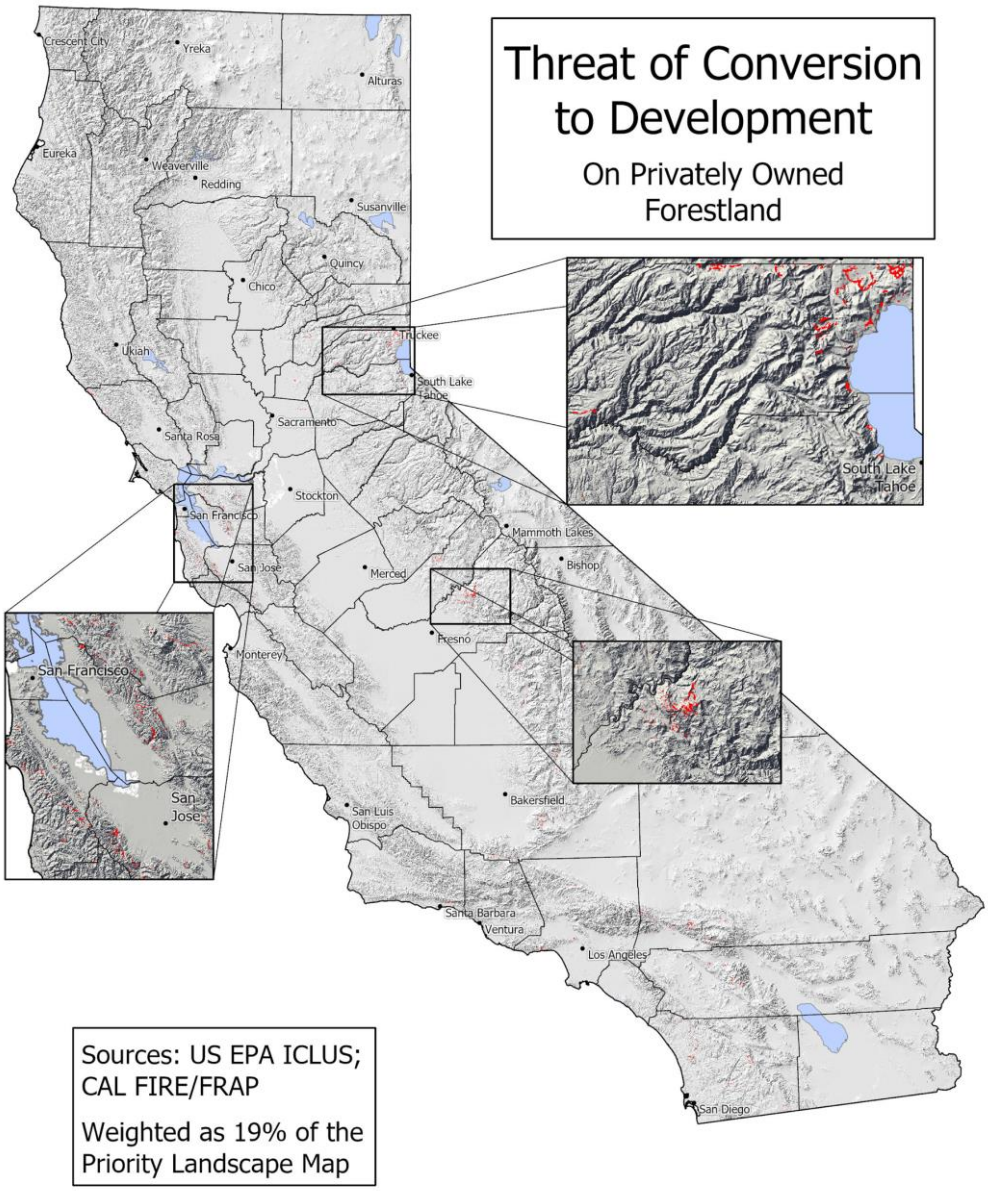
Weighting Factors for Forest Legacy Program Priority Landscapes

Conversion Threat	19%
Public Water Supply	17%
Terrestrial Threatened and Endangered Species Habitat	12%
Habitat Connectivity	12%
Site Productivity	12%
Proximity to Public or Other Conserved Land	12%
Priority Watersheds for State & Central Valley Water Project Supply	10%
ESA-listed Salmon	6%

Maps of Individual Attributes Used in the Priority Area Map

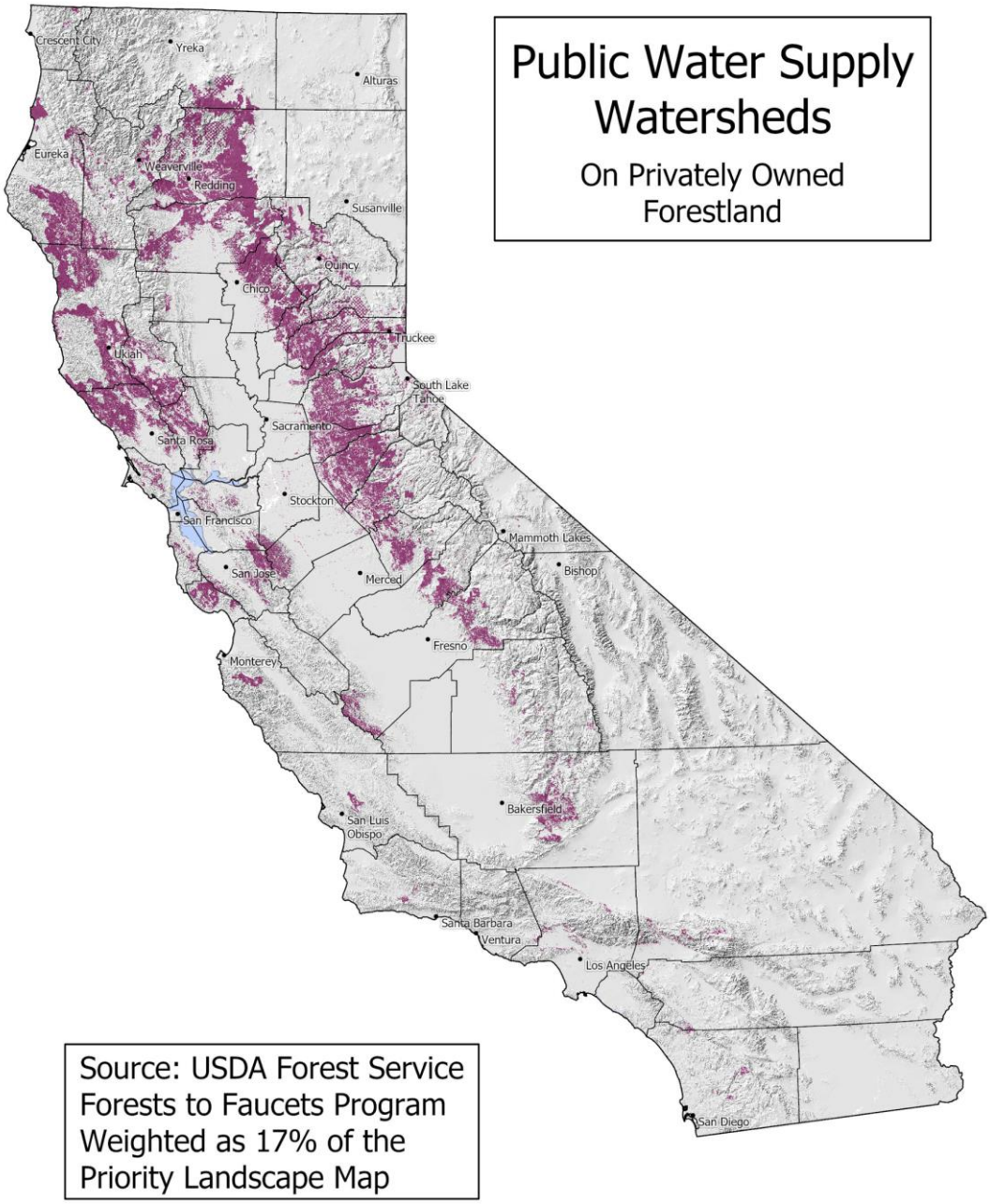
Threat of Conversion to Non-Forest Use

Description: This layer shows outputs from the current US EPA Integrated Climate and Land-Use Scenarios (ICLUS) model to reflect where California is likely to see forestland conversion to residential development by 2060. Conversion is defined as an increase in density from less than one home per 20 acres to more than one home per 20 acres, the threshold California uses to define the Wildland-Urban Interface (WUI). Agricultural conversions were evaluated based on work by FRAP and indicate that most agricultural expansion is occurring in non-forest areas and it is not currently a significant driver for forest conversion. This issue will be monitored and revisited at the next update of this prioritization effort.



Public Water Supply

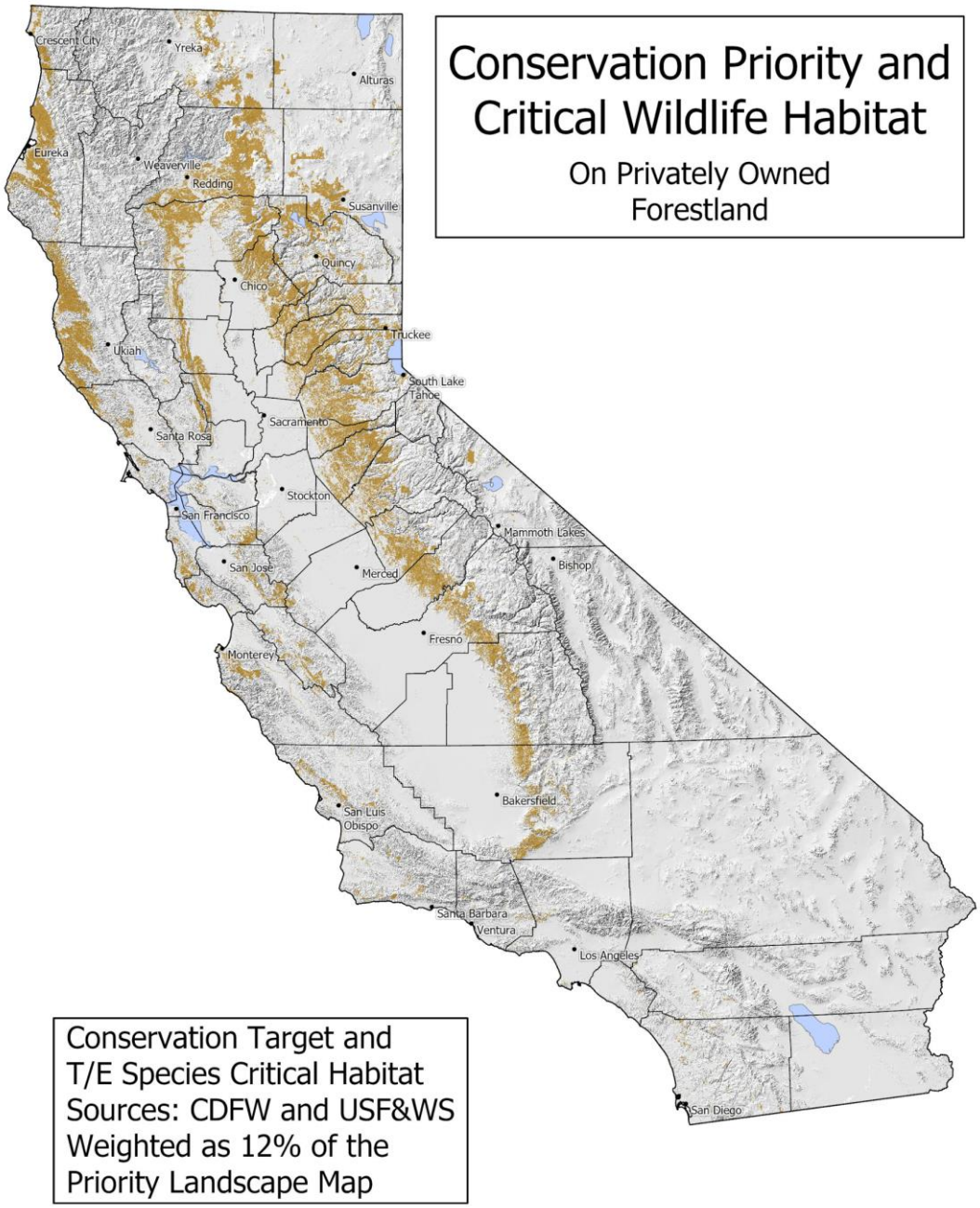
Description: This layer uses the USFS Forests to Faucets data, which depicts watersheds important for protecting surface water resources used for drinking and agricultural water supply.



Terrestrial Threatened and Endangered Species Habitat

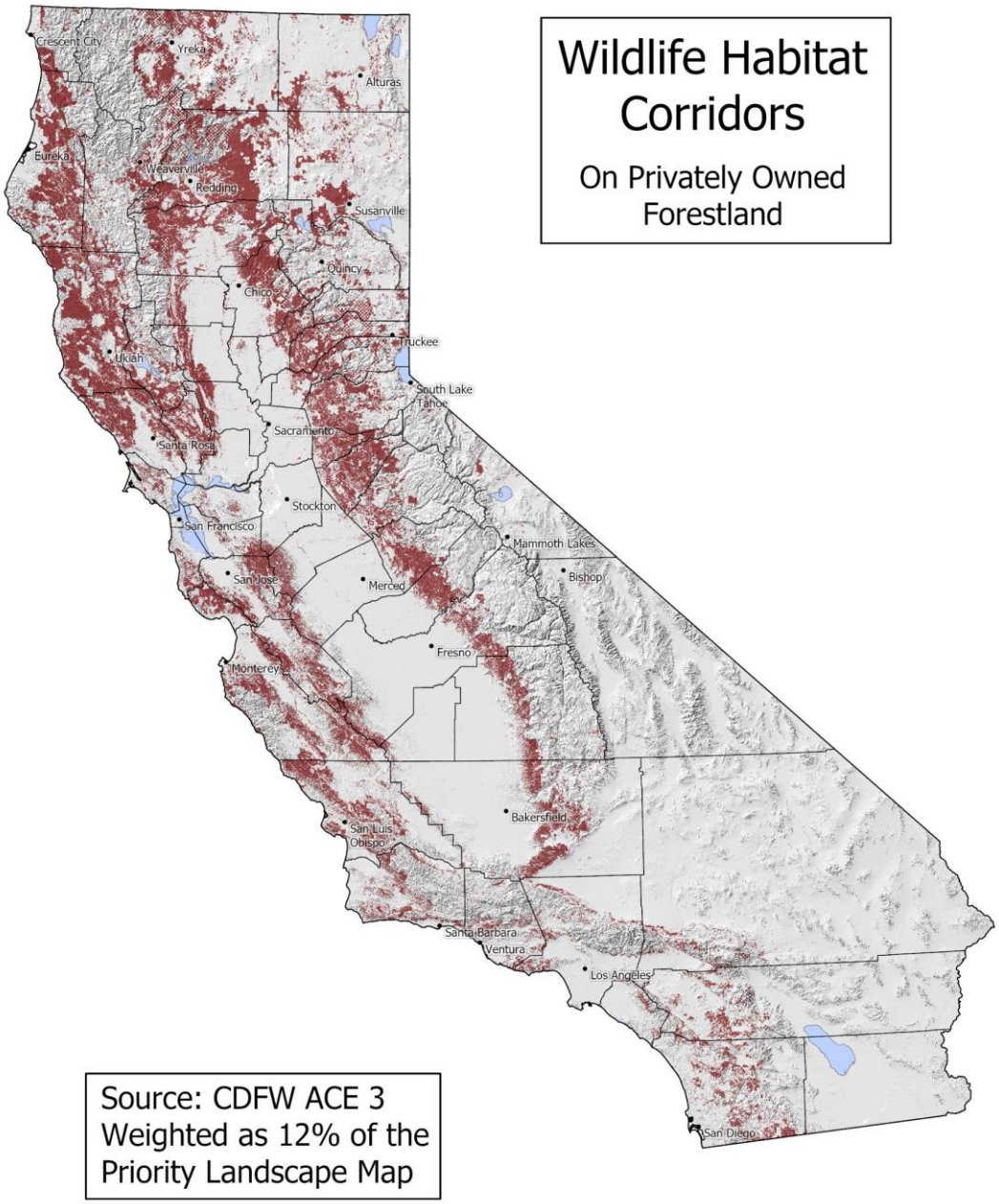
Description: This attribute is addressed by two distinct sets of data, equally weighted:

1) Area designated as Critical Habitat for federally listed threatened or endangered species by the US Fish and Wildlife Service; and,
2) California Department of Fish and Wildlife "Conservation Target" vegetation types from the State Wildlife Action Plan.



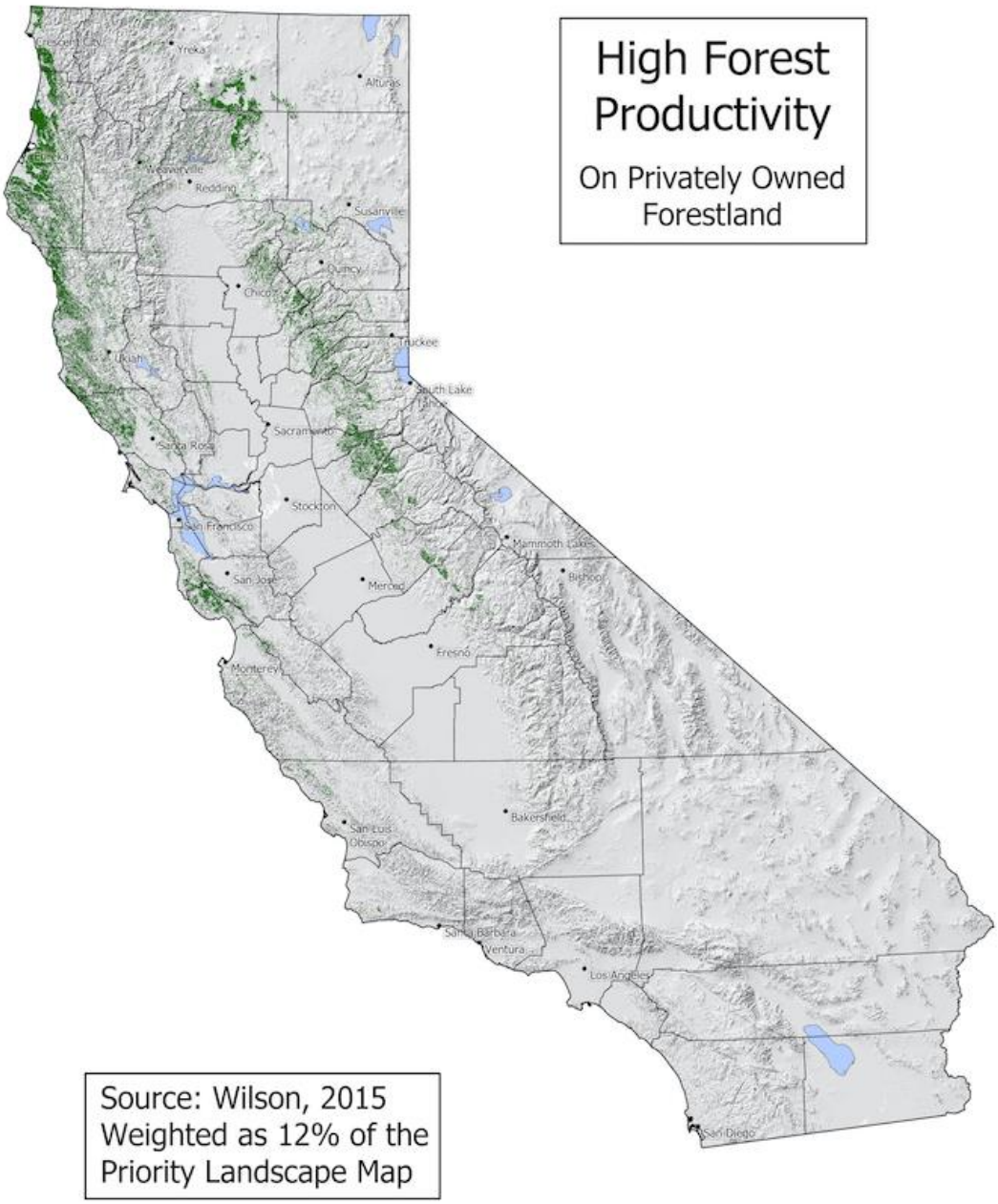
Habitat Connectivity

Description: This attribute recognizes areas of particular importance for wildlife movement and migration. The data is from the California's Department of Fish and Wildlife's Area of Conservation Emphasis (ACEIII) modeling effort.



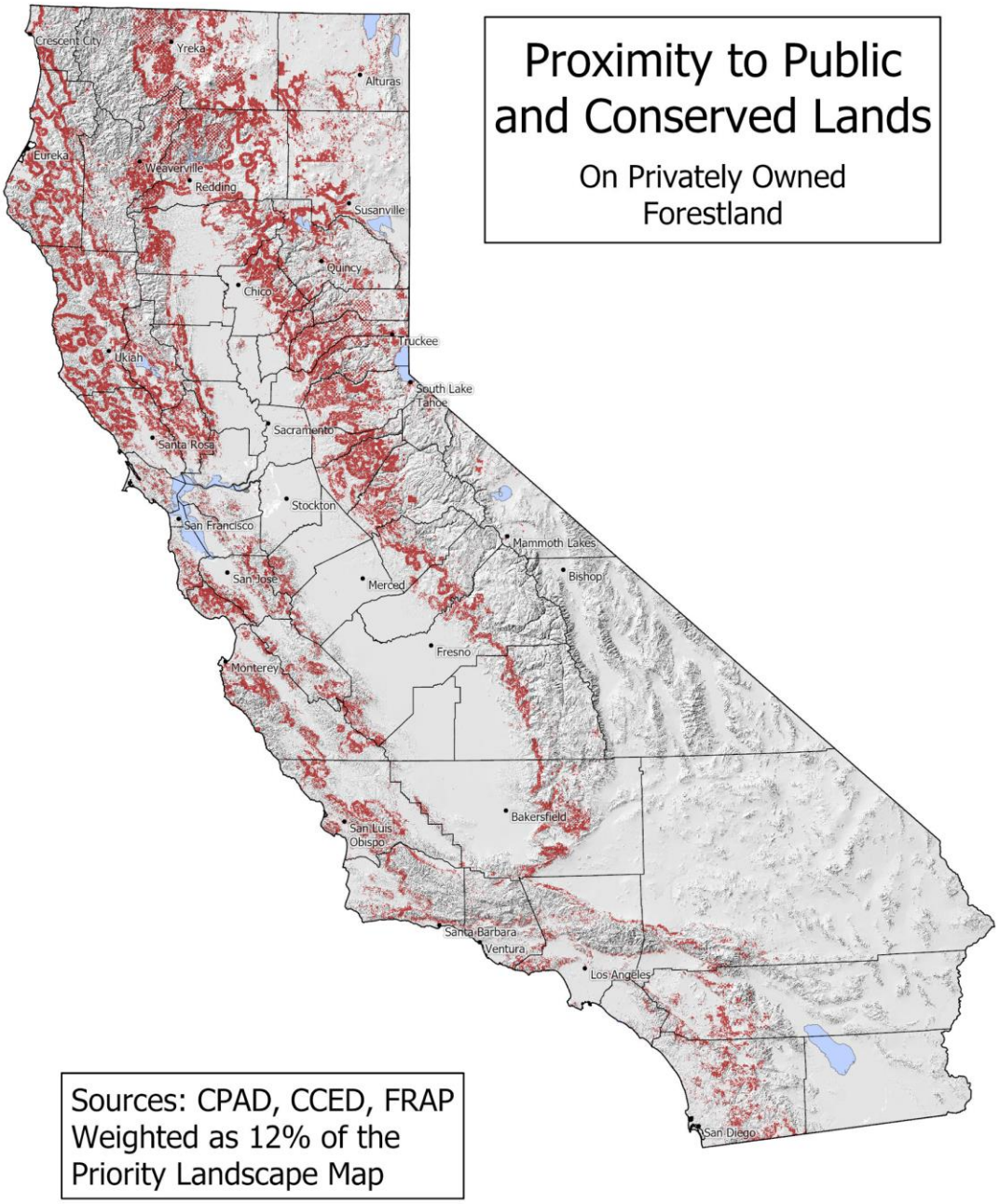
Site Productivity

Description: This attribute is intended to reflect the relative productivity of forest areas, which is a reasonable surrogate for forests likely to be viable for commercial management, and also a rough indication of carbon sequestration potential. Data is from the Forest Inventory and Analysis program, as interpreted by Wilson (2015).



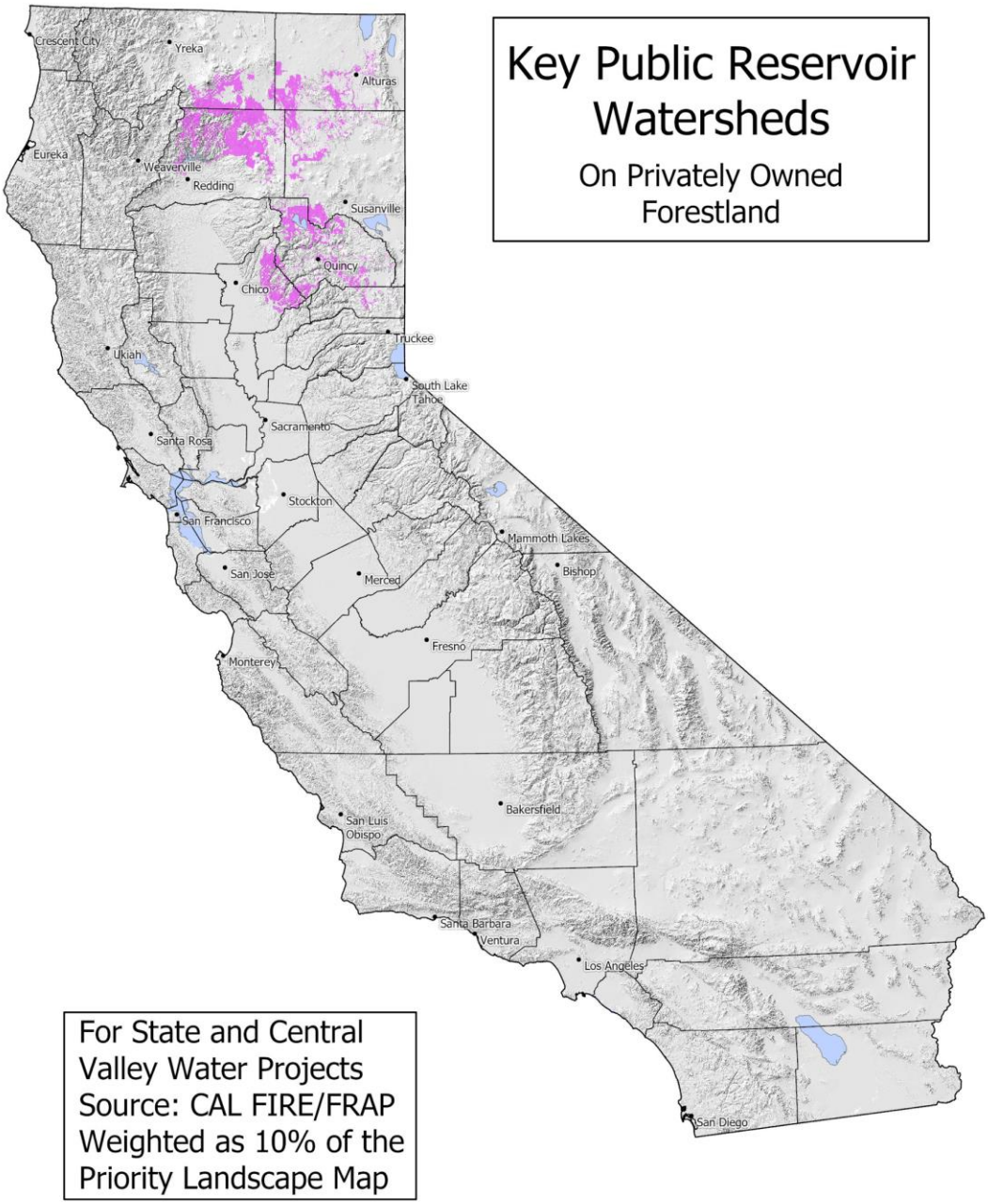
Proximity to Public Land or other Conserved Properties

Description: This attribute is intended to reflect the additional value of locating projects near other conserved land to maximize connectivity for wildlife, and watershed and ecological functionality. This layer is represented by highlighting land within two miles of state and federal public land, or conservation easements included in the California Protected Areas Database.



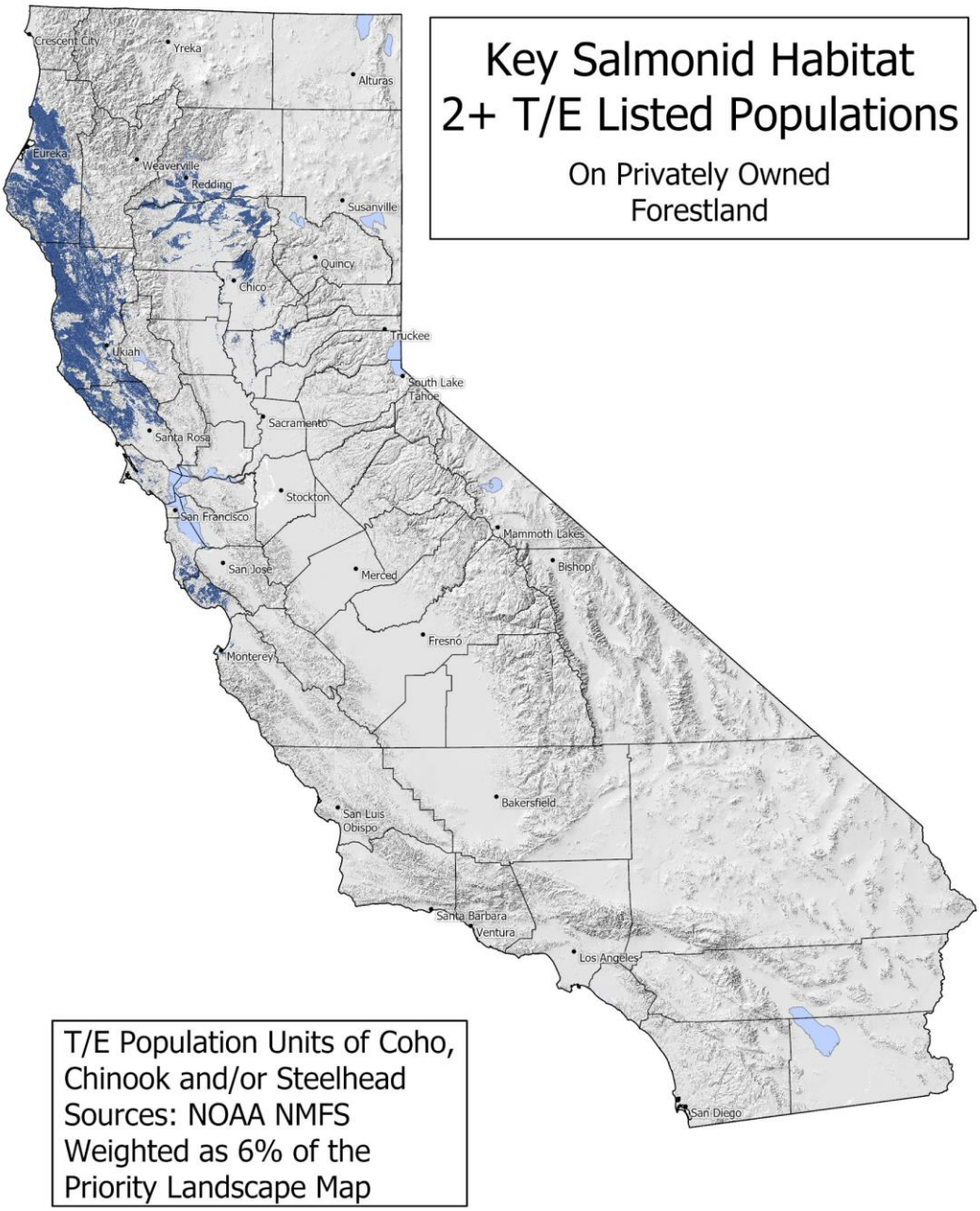
Priority Watersheds for State and Central Valley Water Projects

Description: This layer shows priority watersheds for the Central Valley Project and State Water Project, which supply over 22 million people and most of the state's irrigated agriculture with water. Layer shows watersheds that are ranked as high priority from the 2010 FRAP water storage assessment.



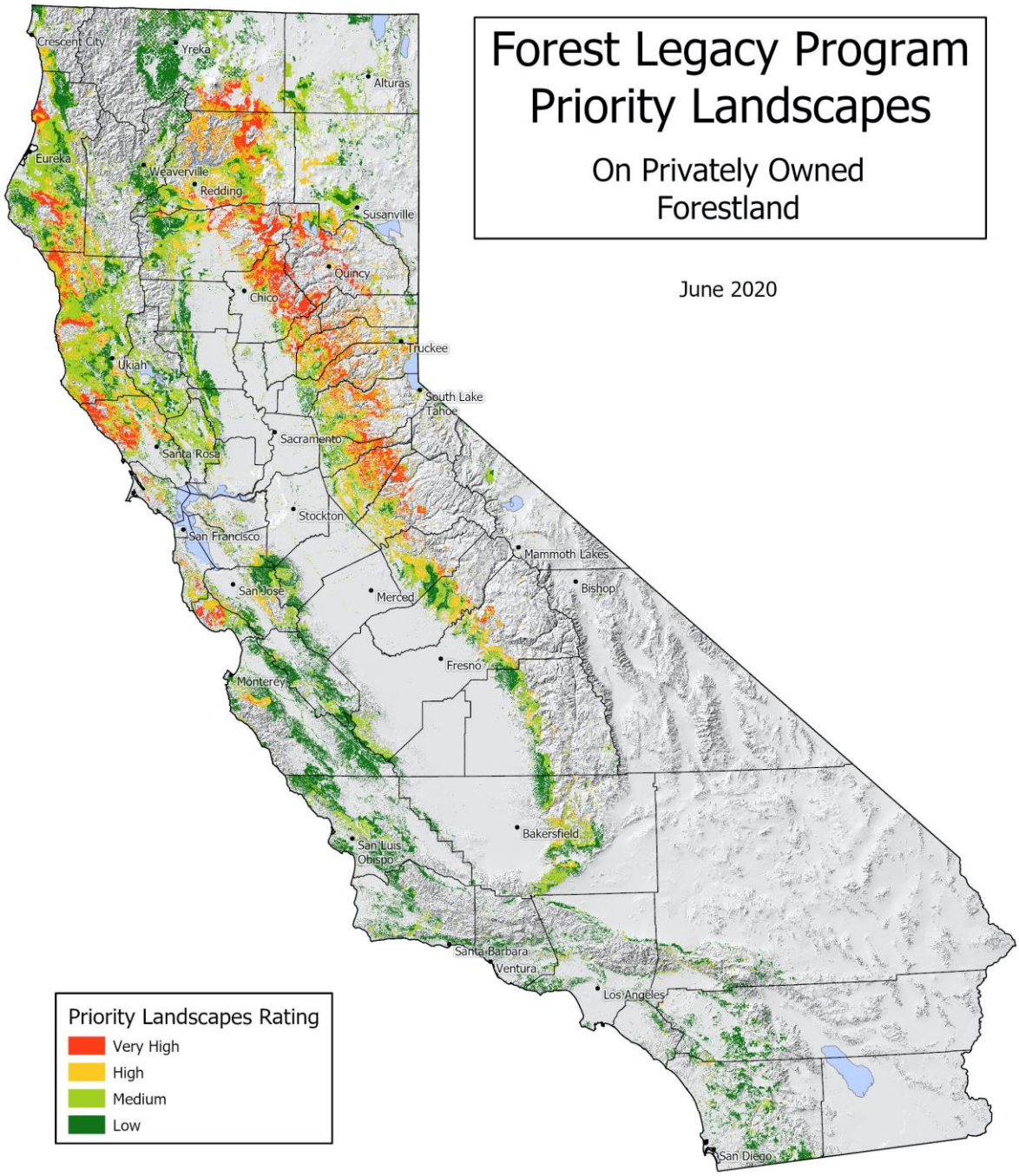
Anadromous Salmon

Description: This layer shows watersheds with at least two listed salmonid species, based on NOAA Fisheries critical habitat designation. This is addressed separately from the terrestrial critical habitat due to the much broader geographic extent.



Final Priority Area Map Integrating the Attributes

Description: The final map integrates and weights the eight attributes to show prioritization. The Priority Ranking categories are based on the default ArcGIS outputs.



This map reflects the following inputs (with weighting factor):
Conversion Threat (19%), Public Water Supply (17%); Terrestrial Threatened and Endangered Species Habitat (12%); Habitat Connectivity (12%); Site Productivity (12%); Proximity to Public or Other Conserved Land (12%); Priority Watersheds for State & Central Valley Water Project Supply (10%); ESA-listed Salmon Populations (6%)

Use of Priority Landscape Map to Evaluate and Prioritize Forest Legacy Project Opportunities

The new Priority Landscape map, used in conjunction with climate projections, will help focus development and evaluation of Forest Legacy projects and opportunities, with the statewide rating providing an initial screening of whether potential projects advance the goals and objectives described above. All proposed projects will ultimately be judged on an individual basis, and site-specific characteristics may drive the selection of projects in areas not prioritized on this statewide assessment.

All projects are evaluated on four main characteristics:

1. **Importance** - Does the land provide important economic, habitat, watershed, water supply, recreational, scenic, and/or historical/cultural benefits?
2. **Strategic Value** - How does the property relate strategically to other properties adjacent or in close proximity to it? Does it improve connectivity, forest resilience, and the cohesiveness of landscape management? How does it rank in the Priority Landscape prioritization?
3. **Threat** - How is the property threatened by development or conversion to other uses?
4. **Readiness** - To what degree has due diligence been completed?

Climate Impacts on California Forests

The changing climate has initiated unprecedented change to California's forests. Areas that have been the same vegetative communities since European settlement are changing to different species and conditions within a single human lifetime. In order to take steps to moderate the extent of change, and help wildlife and communities adapt to future conditions, our conservation and restoration actions need to be informed by the best available projections of likely future climate and habitat conditions. Keeping in mind that Forest Legacy is seeking to accomplish lasting conservation goals, selection of Forest Legacy projects should take anticipated climate impacts into consideration, including both threats to forest resources as well as the anticipated location of more resilient forests.

In 2017 the Department contracted with the University of California at Davis to prepare the report *Range Dynamics of Selected Tree and Shrub Species and Climate Exposure Projections for Forest and Woodland Habitats in California under Four Climate Projections*.[6] Below we excerpt selected graphics of modeled changes in tree distribution and climate stress. The full report evaluates the impact to distribution of 44 tree and shrub species and includes historic climate information, as well as projections for minimum and maximum temperatures, precipitation, climatic water deficit, snowpack (on April 1), and runoff.

[6] Thorne, J. H., H. Choe, J. A. Stewart, and R. M. Boynton. 2017. Range Dynamics of Selected Tree and Shrub Species and Climate Exposure Projections for Forest and Woodland Habitats in California under Four Climate Projections. Information Center for the Environment, University of California, Davis, CA.

The report concludes that:

> Under the current emissions (RCP 8.5) and hotter and drier conditions by end century we found that 15 of the 31 tree species are projected to lose 75% or more of their current climatically suitable range. The tree species that lose 99% or more of their modeled current climatically suitable range are: whitebark pine (*Pinus albicaulis*), red fir (*Abies magnifica, var. magnifica and shastensis*), bigcone Douglas-fir (*Pseudotsuga macrocarpa*), giant sequoia (*Sequoiadendron gigantea*), and Coulter pine (*P. Coulteri*).

The executive summary of the report is appended to the end of this section for additional information.

Projections of future climate conditions, and impacts on hydrology, temperature, and vegetative communities, are regularly being refined and updated. Below we provide a few sample maps illustrating the state-wide impacts from climate change based on the currently best available projections as of the summer of 2020.

Changes in Maximum Temperature

Maximum temperatures throughout the state are projected to increase in the future compared to 1981-2010 averages (Figure 6). While temperature will increase significantly by the middle of the century (Figure 7), it is projected to increase far more dramatically by later in the century (Figure 8).

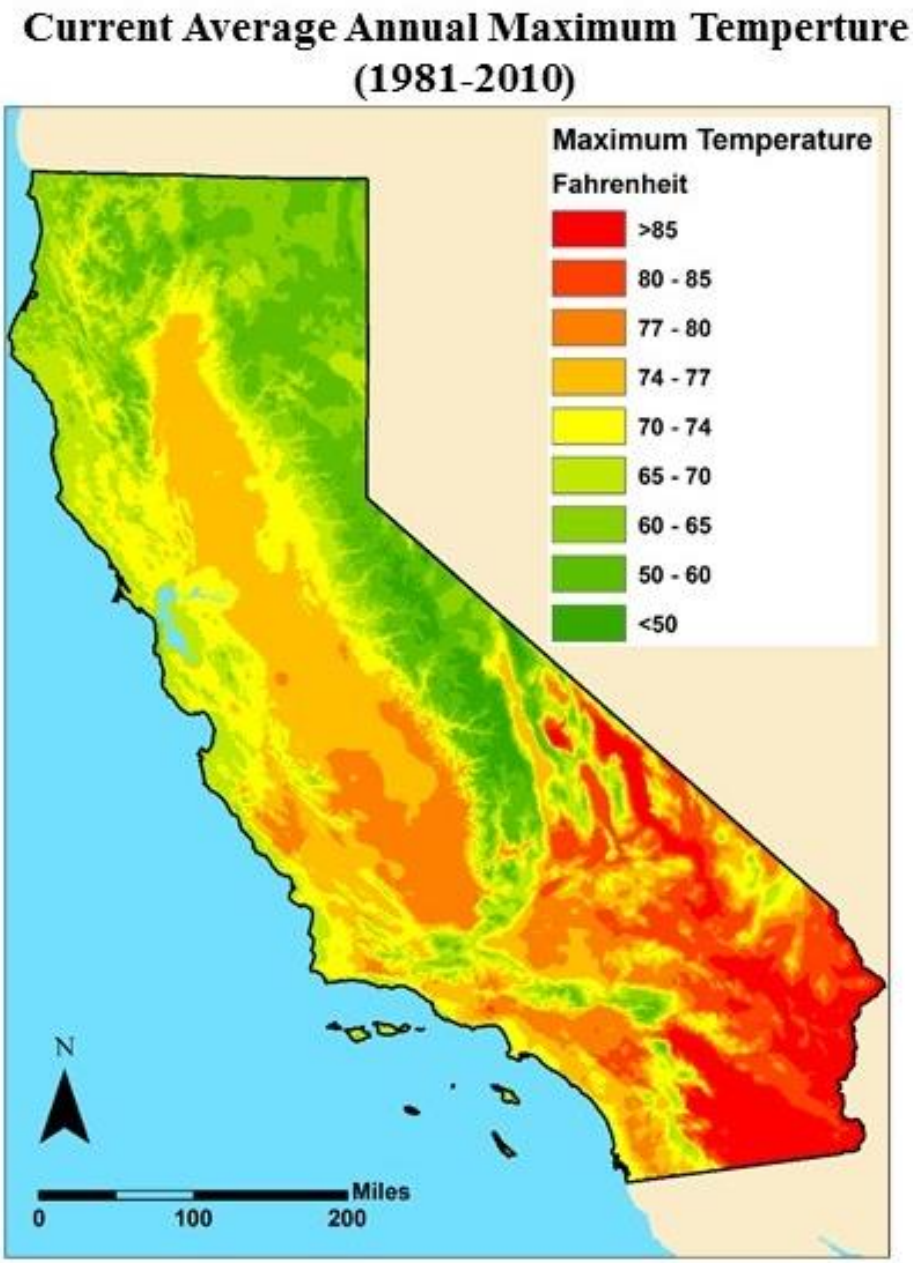


Figure 6. Current average annual maximum temperature (1981-2010) for California.

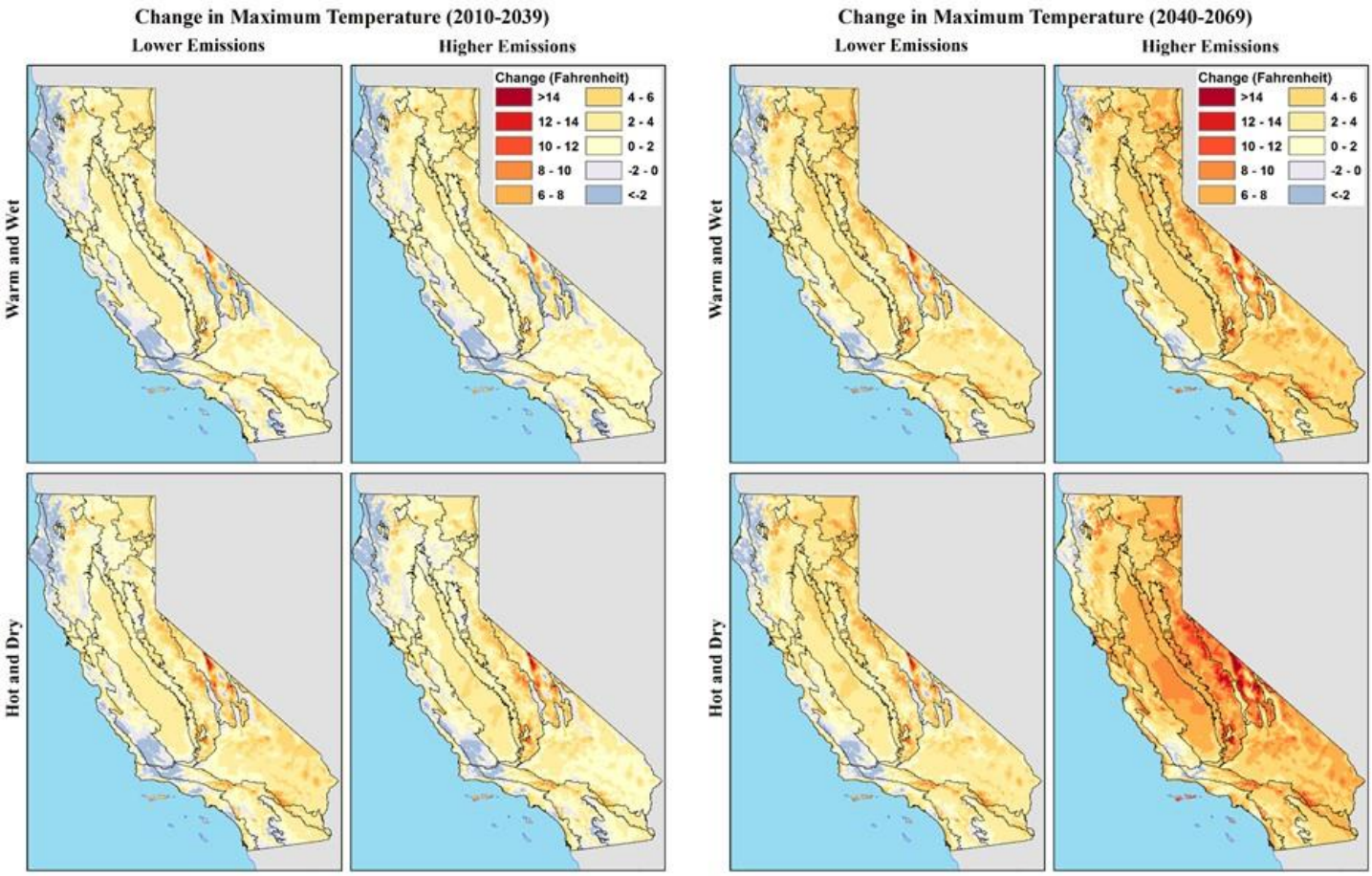


Figure 7. Change in maximum temperature by 2010-2039 and 2040-2069, compared to 1981-2010 temperatures, under four climate scenarios. Current global climate-warming emissions are more consistent with the higher emission scenario.

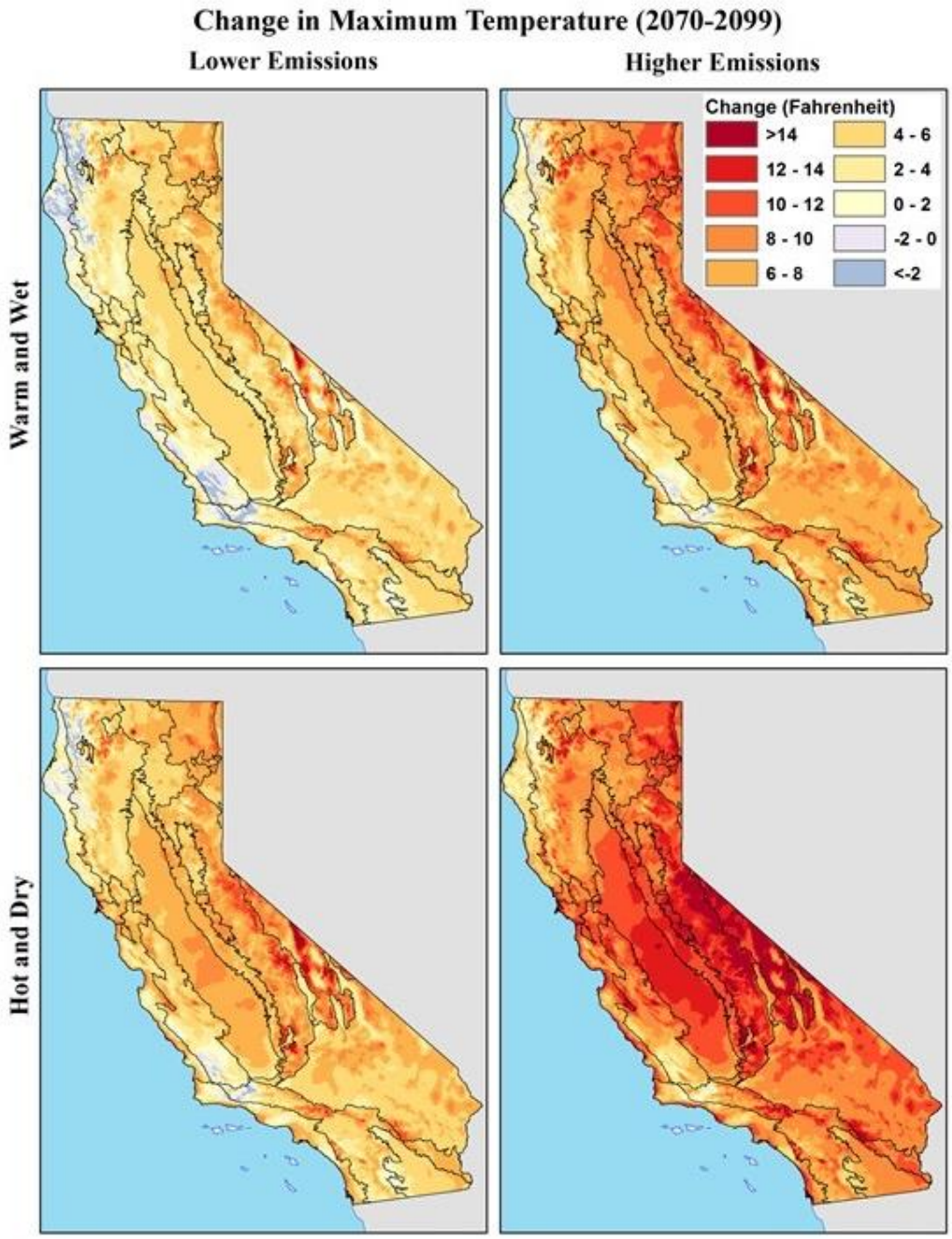


Figure 8. Change in maximum temperature by 2070-2099, compared to 1981-2010 temperatures, under four climate scenarios. Current global climate-warming emissions are more consistent with the higher emission scenario.

Changes in Species Distribution by Late in the Century

Tree species distributions are also projected to change significantly (Figures 9 and 10). Note that the projected distribution is based on climate conditions and does not account for other limitations, such as suitable soils. Therefore the future range is likely to be over-represented.

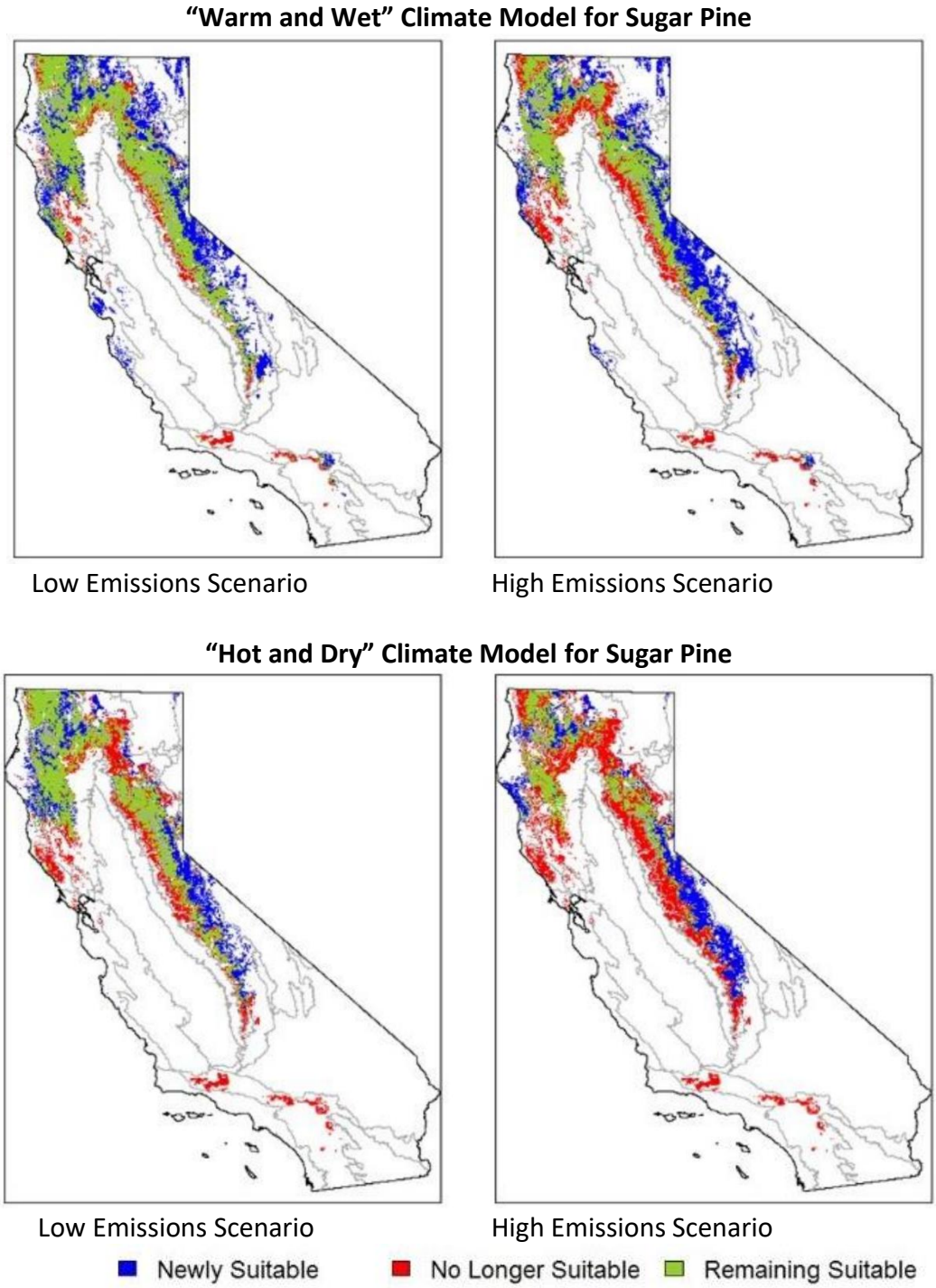
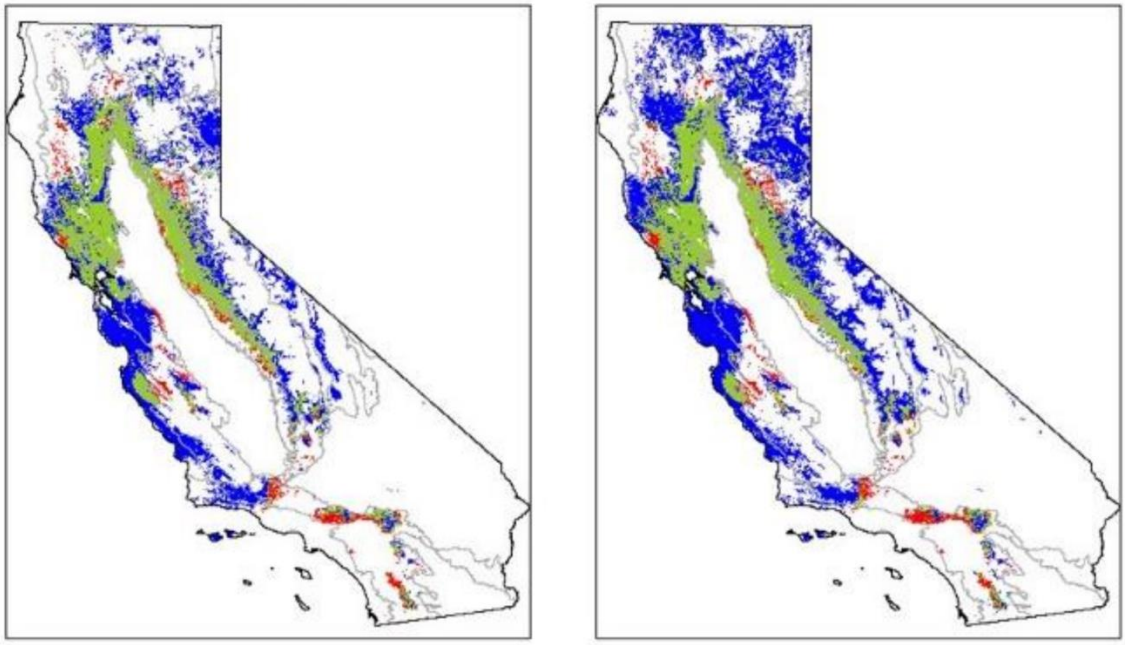


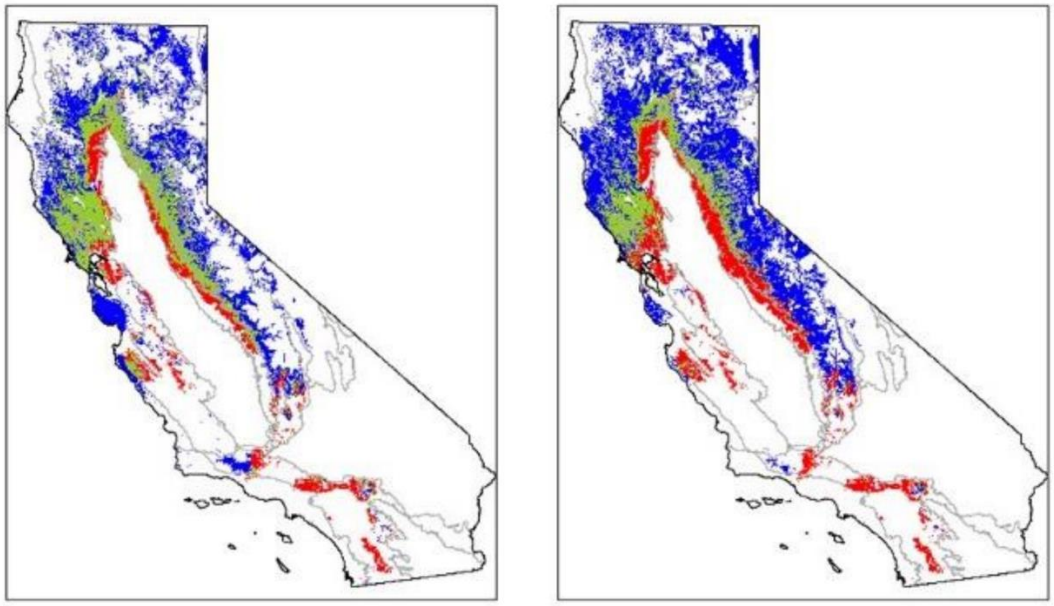
Figure 9. Sugar Pine habitat range changes by 2070-2099 under four climate scenarios. Note much of the "newly suitable" habitat is in the high Sierra and lacks appropriate soils.

"Warm and Wet" Climate Model for Interior Live Oak



Low Emissions Scenario High Emissions Scenario

"Hot and Dry" Climate Model for Interior Live Oak



Low Emissions Scenario High Emissions Scenario

Newly Suitable No Longer Suitable Remaining Suitable

Figure 10. Interior Live Oak habitat range changes by 2070-2099 under four climate scenarios.

Executive Summary from *Range Dynamics of Selected Tree and Shrub Species and Climate Exposure Projections for Forest and Woodland Habitats in California under Four Climate Projections*[7]

This report provides a summary of data and models produced for the California Fire and Resource Assessment Program (FRAP) by the University of California, Davis. Products from this study are meant to support ongoing planning and reports by FRAP to other state agencies, for planning purposes and for outreach to the public. In particular they are intended to help identify dominant forest species' vulnerability to climate change. The project produced a series of characterizations of future climate conditions in California by end century for two Global Climate Models (GCMs) and two emission scenarios (RCP 4.5 and RCP 8.5), representing a gradient of futures from warmer and wetter to hotter and drier. These futures represent average conditions for three future time periods: 2010-2039, 2040-2069, and 2070-2099, and we term the last time step "end of century". We assembled climate, habitat, and species-level data, and used them to produce two types of forecasts: a series of species distribution models for 45 tree and shrub species; and an assessment of climate exposure for the existing extents of six California Wildlife Habitat Relationship types that represent the majority of California's forests and woodlands.

Currently, global emissions are closer to the higher level emission scenario used in this study (RCP8.5), and the more optimistic scenario used in this report to bracket the results (RCP4.5) would require considerable resolve and action to achieve. However, California has committed to an endeavor to reduce its carbon footprint, and we therefore include the RCP4.5 analyses to represent the potential lower climatic impacts that might be achieved by the end of century.
Under the warmer and wetter GCM (CNRM CM5) annual minimum temperatures increase by 1.39°C and total annual precipitation increases by 20.6% under the RCP4.5 emissions scenario, and by 3.26°C and 34.67% (+ 5.8 inches) under the RCP8.5 emissions scenario. Under the hotter and drier GCM (MIROC ESM), mean annual minimum temperatures increase by 1.92°C under the RCP4.5 and 3.95°C under the RCP8.5 emissions scenarios, and total annual precipitation decreases by 19.97% and 26.21% (-6.9 inches) under the RCP4.5 and RCP8.5 scenarios, respectively.

Under the current emissions (RCP 8.5) and hotter and drier conditions by end century we found that 15 of the 31 tree species are projected to lose 75% or more of their current climatically suitable range. The tree species that lose 99% or more of their modeled current climatically suitable range are: whitebark pine (*Pinus albicaulis*), red fir (*Abies magnificavar magnifica and shastensis),* bigcone Douglas-fir (*Pseudotsuga macrocarpa*), giant sequoia (*Sequoiadendron gigantea*), and Coulter pine

[7] Thorne, J. H., H. Choe, J. A. Stewart, and R. M. Boynton. 2017. Information Center for the Environment, University of California, Davis, CA.

(*P. Coulteri*). Tree species that retain the most of their modeled current climatically suitable range include valley oak (*Quercus lobata*) (73% retained), blue oak (*Q. douglasii*) (58%), and California black oak (54%) (*Q. kelloggii*). For shrubs, 10 of the 14 species gain climatically suitable range, but three shrubs lose more than 88% of their current climatically suitable range: greenleaf manzanita (*Arctostaphylos patula*), bush chinquapin (*Chrysolepis sempervirens*), and black brush (*Coleogyne ramossissima*). The shrubs that retain the most area of their current climatically suitable range are white bursage (*Ambrosia dumosa*), California buckwheat (*Eriogonum fasciculatum*), and creosote bush (*Larrea tridentata*). The shrub species that gain the most newly climatically suitable range include California buckwheat, chamise (*Adenostoma fasciculatum*), black brush, and white bursage.

Under the current emissions (RCP 8.5) and warmer and wetter conditions by end century, we found that 7 of 31 tree species modeled are projected to lose 75% or more of their current climatically suitable range. Two tree species lose over 99% of their current climatically suitable range, which they also do under the hotter and drier scenario: whitebark pine and red fir. For shrubs under the same GCM/emission scenario the most climatically suitable range is lost for greenleaf manzanita, bush chinquapin, and black brush. The shrubs that retain the most area of their current climatically suitable range are the same as for the hotter and drier scenario: California buckwheat, white bursage, and creosote bush. The shrub species that gain the most newly climatically suitable range include: sticky whiteleaf manzanita (*A. viscida*), chamise, coyote brush (*Baccharis pilularis*), and deer brush (*Ceanothus integerrimus*).

For the six forest and woodland habitat types (Eastside Pine, Klamath Mixed Conifer, Montane Hardwood, Montane Hardwood Conifer, Red Fir, Sierran Mixed Conifer), we defined climate stress as the current climate conditions found in only 5% of their currently mapped range, while the more common conditions found in 80% of each type's mapped area were considered neutral or not-stressed. We then tracked the progression of climate conditions in every pixel of each habitat type, and identified how many (how much area) transitioned into the climate stressed category. The overall proportion of forest and woodland habitats that become climatically stressed by the end of century under the current emission levels (RCP8.5) is 44% under a wetter and warmer GCM and 50% under the hotter and drier GCM. Under the lower RCP4.5 emissions level the climate exposure of forest and woodland habitats in California is 20% for both the wetter and the drier GCM model tested.

Technical Notes

GIS Analysis conducted by:
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Research Program Specialist
Fire and Resource Assessment Program (FRAP), CAL FIRE
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Based upon input from the FSCC, the following factors were selected for ranking forested landscapes as potential candidates for FLP projects and funding, each with their original relative importance according to priority ranking decisions made by a subcommittee:

- Conversion threat (13%)
- Public water supply (13%)
- Listed/sensitive species critical habitat (12%)
- Climate threat exposure (12%)
- Habitat connectivity/corridors (11%)
- Soil/site productivity (9%)
- Proximity to public and other conserved lands (8%)

After much consideration, CAL FIRE and the contractor decided that the Climate Threat Exposure criteria was difficult to integrate into the Priority Landscape map and that the climate exposure and resilience maps (from the California Department of Fish and Wildlife and Thorne et al.) are best used alongside – but distinct from – the Priority Landscape map.

After further discussion and consideration, the following input factors and weights were decided upon:

- Conversion threat (19%)
- Public water supply (17%) (Forest2Faucet source); and key reservoir watersheds (FRAP source) (10%)
- Listed/sensitive terrestrial species critical habitat (12%); and anadromous salmonid habitat (6%)
- Habitat connectivity/corridors (12%)
- Soil/site productivity (12%)
- Proximity to public and other conserved lands (12%)

For the above inputs, high quality candidate GIS data sources were reviewed for their suitability/applicability. In some cases (public water supply, critical habitat), data were split into two feeds weighted independently and based on different sources. Below is a brief summary for each.

Preamble: Producing the Forest Legacy Priority Landscape Land Base

The statewide land base domain upon which the Forest Legacy Program may operate was also necessary to produce. The criteria were set as follows:

- Only lands in private ownership
  - FRAP ownership GIS layer
- Only those lands in forested (or potentially forested) types
  - CALVEG_2015
    - Attribute PROD = N or P (able to support >= 10% of vegetation canopy in forest tree species – includes a lot of land currently in chaparral types)
    - For areas missing in coverage (San Benito, San Luis Obispo Counties) an older CALVEG layer was used
  - FVEG15 (FRAP statewide vegetation layer)
    - Forest types based on CDFW Wildlife Habitat Relationship (WHR) types
  - Removed areas of potential forest currently in intensive agriculture
  - Corrected for areas regenerating from recent timber harvest and stand-replacing wildfires and that are not typed as "forestland" in existing vegetation cover GIS layers (FVEG, CALVEG, LANDFIRE, etc) so that they are included in the land base.
- Lands in montane meadow types
  - FVEG15 Wet Meadow WHR type
  - Sierra Meadows Project GIS layer

The land base layer described above provides the GIS raster "mask" that keeps candidate areas and eliminates lands unavailable to the FLP (for whatever reason) from consideration in the final GIS and map outputs.

A note on GIS layer creation for this program: all GIS layers used as weighted inputs to the final priority landscape (described below) are binary (yes/no) rasters at 30m spatial resolution. For each category of input, data were processed into statewide GIS layers in this binary form to show areas that are important versus those that are not, according to the specific data and criteria used.

Conversion Threat (19% of total weight)

For the 2017 Forest and Rangeland Assessment, FRAP put substantial effort into updating the Integrated Climate and Land Use Scenarios (ICLUS) model used by the US Environmental Protection Agency (see https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=203458) with 2010 Census Bureau data and county population projections from the Department of Finance. It produced a spatially-explicit set of GIS layers showing where the model predicted that increased housing densities would occur in the 2040 to 2060 timeframe.

The threshold criteria FRAP used to determine "conversion to development" from the modeled data was the increase of housing density from below WUI density (<=1 housing unit per 20 acres) to at or above the WUI density.

In terms of statewide threats, the modeled conversion of forestland to development is highly localized. These include the Truckee area at Lake Tahoe, the forested coasts near the Bay Area, and a few other areas (e.g. Shaver Lake in Fresno County). Overall, it comprises few acres. In contrast, development threat by the same criteria and timeframe to rangeland, and especially lands currently in intensive agriculture, is substantial.

Based on prior assessment by FRAP, vineyard conversion is not seen as a significant driver of forest loss. Those impacts have been limited to coastal areas, and thus far few acres of forest have been converted to vineyards. New vineyards have been primarily planted in naturally occurring forest openings.

Public Water Supply (17% and 10% of total weight, respectively)

This was broken into two GIS input feeds, from different source data:

US Forest Service's Forests to Faucets Program (17%)

This program (see https://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml) publishes GIS layers nationwide that rank watersheds of various scales that supply drinking water, according to the importance value criteria the program developed. The value is on a relative scale; we selected the top-tier of watersheds that provide water to municipalities (IMP >= 60) that appeared to represent key water supply areas of the state.

Fire and Resource Assessment Program 2010 Forest and Rangelands Assessment water storage asset (10%)

We selected from this layer the watersheds ranked as "high." Description from the metadata: "*The GIS layer represents the watersheds in California that contribute significantly to municipal water supply for the state. The layer was derived by locating major reservoirs in the state of California and then delineating their catchment area. The total storage for the catchment area was summarized and then ranked high, medium, or low according to amount of water stored. A high ranking represents areas that provide the most water, medium represents a medium amount of water, and low represents areas that supply a small amount of water.*"

Listed T/E Species Critical Habitat and SWAP Conservation Targets, and (as a separate feed) Anadromous Salmonid Critical Habitat (12% and 6% of total weight, respectively)

The critical habitat designations of terrestrial threatened and endangered species was taken from the US Fish and Wildlife Service (USFWS) GIS layer showing all such habitat (for species listed under the federal Endangered Species Act), and terrestrial habitat was supplemented with the Conservation Target vegetation types produced for the State Wildlife Action Plan (SWAP) by USFWS Areas of Conservation Emphasis program (ACE 2).

Note that the USFWS critical habitat designations occur primarily on non-private lands, thus only a few species (marbled murrelet and some amphibians) affected private forested lands.

The layer produced by the CDFW for the vegetation types targeted for conservation suffered from some significant defects, due to its using FVEG15 as the primary source of the vegetation extents:

- Substantial areas of forestlands have burned in recent years, and in some cases, these are not shown as forest types in FVEG15 GIS layer (which by definition shows the current vegetation cover).
- Some areas that have potential to be forested are not currently in forested types (in FVEG15 and other existing vegetation cover layers) for other reasons:
    - Recent clear-cut forest areas appear as non-forest types in vegetation layers and would therefore be excluded from this input to the final product.
    - To fill in these GIS "holes," other GIS layers were found and used, which showed the clear cuts in a forested state. These "holes" in the target forested types were numerous and occurred mainly on mid-elevation industrial timberlands on the west side of the Sierra Nevada and southern Cascades, and on redwood forestlands along the north coast.

To correct for these omissions, a few key GIS layers were researched and used, primarily the CALVEG_2015 layer with attribute SAF_TYPE. Deriving GIS layer areas of critical habitat for the three main species of listed anadromous salmonids (coho, chinook, and steelhead) entailed significant work. These species are listed as threatened or endangered on the basis of designated metapopulations (termed Evolutionary Significant Units (ESUs) or Distinct Population Segments (DPS). That is, each anadromous species is listed (or not) on a regional basis.

First, GIS layers of streams designated as critical habitat for the various T/E salmonid populations were obtained, then buffered and intersected with the HUC12 watershed units which they were a part of. HUC12s were tagged as being "critical habitat," and HUC12s were summed as to the number of listed species (coho, chinook, and steelhead) they contained (1 to 3). Those HUC12s that were listed as critical habitat for 2 or more federally listed salmon species were kept. This eliminated all HUC12s in the Klamath/Trinity drainage system (where only coho is listed), and a number of HUC12s along the central and southern California coast (where only steelhead is listed).

Habitat Connectivity/Corridors (12% of total weight)

The Areas of Conservation Emphasis (ACE 3) program of the CDFW produced a statewide GIS layer of essential habitat connectivity, called the Terrestrial Connectivity Layer (ds2734). This is an update from a previously published layer, made for the same purpose, produced for CAL TRANS. Areas deemed important for corridors included in this layer were:

- Irreplaceable and Essential Corridors;
- Conservation Planning Linkages;
- Connections with Implementation Flexibility; and

- Large Natural Habitat Areas (which excluded only Limited Connectivity Opportunity lands).

Soil/Site Productivity (12% of total weight)

Wilson (2015) of the USFS produced a GIS layer of forest productivity based on Forest Inventory and Analysis (FIA) data, which includes both productive (i.e. able to produce commercial timber) and non-productive (other) forestlands. We used standard site classes of 1 through 3 from that GIS layer to represent the highest productivity forestlands in the state.

Proximity to Public and Other Conserved Lands (12% of total weight)

For this input GIS layer, data from the Conserved and Protected Areas (CPAD) and Conservation Easements (CCED), as well as ownership (non-private lands) were used as spatial "centers," from which buffer areas were created that extend out two miles.