Sierra Nevada Regional Resource Kit Metric Dictionary (Raw Data)

Lead Contributors: Laura Young-Hart, Peter Stine, Patricia Manley, Carol Clark

Additional Contributions: Liraz Bistritz, Michael Goulden, Elliot Kuskulis, Carlos Ramirez, Michèle Slaton, Joseph Stewart, Leland Tarnay, Derek Young

Update: 15 January 2024, v.4.3 (updated Sierra Nevada Regional Resource Kit)

Update: 18 October 2023, v.4.2 (updated Sierra Nevada Regional Resource Kit)

Update: 15 March 2023, v.4.1 (updated Sierra Nevada Regional Resource Kit)

Update: 23 January 2023, v.4 (FIA Credit/Disclaimer & Data Clarifications)

Update: 28 October 2022, version 3.0 (ACCEL Data Products)

Revised: 23 September 2022, version 2.0 (Regional Resource Kit)

28 September 2021, version 1 (Initial Metric Ambitions)

Table of Contents

Introduction

What is the Regional Resource Kit effort?

The data layers included in this Sierra Nevada Regional Resource Kit were originally developed by the U.S. Forest Service "ACCEL" program, a joint effort of the Pacific Southwest Research Station and Region 5. The transition to the Regional Resource Kit reflects the growth of the partnership to include interests of the California Wildfire and Forest Resilience Task Force and academic scientists from UC Berkeley and UC Irvine who have been developing information that contributes to this overall effort. As we continue to develop additional geospatial data for landscape assessment and planning throughout the state this partnership has now taken the lead in the creation of the Regional Resource Kits for the four regions of California.

The Task Force is committed to increasing the "pace and scale" of forest treatments in California. Multiple federal and state initiatives in the last few years detail this commitment. The Forest Service developed the "Wildfire Crisis Strategy Implementation Plan" (2022), a program to work with land management partners to co-manage fire risk across broad landscapes. The State of California issued a "Wildfire and Forest Resilience Action Plan" (January 2021) designed to strategically accelerate efforts to restore the health and resilience of California forests through a joint State-Forest Service framework to enhance stewardship in California. In all cases, land managers need support to plan and implement treatments to address restoration at a landscape scale.

An essential component of these initiatives is the spatial data representing landscape conditions and new analytical tools for planning management investments. Pacific Southwest Research Station (PSW) scientists and staff from Region 5 Information Management, Mapping and Remote Sensing (MARS) Team, joined forces to develop and/or collect and assemble existing sources of spatial data. This project, originally referred to as the ACCEL project (for accelerating pace and scale of treatments), combined the expertise and experience of research and management to build this library of data on landscape conditions. It has now been adopted as the Sierra Nevada Regional Resource Kit (SNV RRK).

The first iteration of the Sierra Nevada Regional Resource Kit (RRK) dates back to September 2022. Since that time we have both updated a number of the data layers in the RRK as well as identify additional data layers to add to this RRK. This version reflects these updates/additions through January 2024. Changes and additions are noted on the Sierra Nevada RRK webpage.

What this document is and its intended purpose

Organizational Structure

This document has been organized to reflect the "Framework for Resilience" as set forth by the Tahoe Central Sierra Initiative (Manley et al. 2020, 2022). The framework comprises ten "**Pillars**" which support the full array of landscape management objectives that are inherently interdependent. Each pillar represents the desired long-term, landscape-scale outcome to restoring resilience. They include ecological values, such as biodiversity, as well as societal benefits to communities, such as water security. Within each pillar are "**Elements**" which represent the primary processes and core functions of that pillar, such as focal species, water quality, or economic health. Finally, within each element are the individual "**Metrics**" which describe the characteristics of elements in quantitative or qualitative terms. Metrics are used to assess, plan for, measure, and monitor progress toward desired outcomes and greater resilience.

The framework pillars are:

- Fire Dynamics
- Forest and Shrubland Resilience
- Biodiversity Conservation
- Wetland Integrity
- Water Security
- Carbon Sequestration
- Air Quality
- Economic Diversity
- Fire Adapted Communities
- Social & Cultural Well-Being

It is important to understand that while pillars and elements are consistent across California, the metrics used by a group may vary from region to region based on ecological and social differences (for example forest types or economy), available data, and the user preferences. It is equally important to recognize that due to the interdependent nature of the framework, some metrics overlap into multiple elements/pillars however have only been addressed a single time within this document. Each pillar represents a resource outcome associated with resilient forest landscapes.

Landscape level assessments, using high-quality data combined with decision support tools to help evaluate alternative treatment strategies, are fundamental to inform and support large landscape restoration planning. These data have been assembled in one place to provide comprehensive access for land managers.

Metrics

The metrics are organized under the 10 pillars. There are 114 metrics within the Sierra Nevada Regional Resource Kit. The Metrics describe the characteristics of the elements (key characteristics) of each pillar in quantitative or, in a few cases, qualitative terms. Metrics are used to assess current conditions, plan treatments, and monitor for, measure, and monitor progress toward desired outcomes and greater resilience. Metrics are selected to be informative, meaningful, and actionable to meet the needs of management.

The metrics included within this Sierra Nevada Regional Resource Kit are divided into three "tiers." Among all these metrics, some are created and relevant statewide. Additional metrics are more suited to issues/conditions within a given region. The "Tiers" for metrics included in each RRK:

- ***Tier 1*** – metrics that are relevant to two or more Regions and a single, consistent data layer is available and provided; can be clipped to the boundary of the region so values within that region are the only ones included for calculations or regional statistics. Example: *Annual Burn Probability*
- ***Tier 2*** – metrics relevant to a single region or relevant to multiple Regions but data layers differ among Regions because of varied data availability (sources) across Regions. Example: *Pacific Marten*
- ***Tier 3*** - metrics are those that would be of interest to some land managers for specific applications but not included as a core metric in an RRK. Example: *Biomass Residues*

Within each Tier, the data layers are available in two forms: 1) **data values native to the metric (raw)**, defined in this metric dictionary, and 2) **translated data values**. Please see the separate metric dictionary for the translated data and explanations for what those mean and what they are intended to provide.

Some data layers within this kit contain null values. We point this out here so users of the data will be aware and take whatever measures appropriate as they use and analyze the data. For some raster datasets in the RRK, areas have been masked (blanked) out and have a cell value of NoData (also referred to as null, NaN or missing). We, as producers and users of the data, cannot ignore NoData or fill them with zeros, since zero is often a valid value for some datasets. Removing NoData cells is not an option, a raster is a continuous grid. For users of the data performing further analyses and combining or "stacking" rasters, these NoData cells will mask out all values in that location in the output. To avoid this issue, the user must create values for the cells before combining them (i.e. 999 or any numeric value that is not real and clearly out of the range of the other values). Reasons for masking (blanking) out cells in RRK data include:

- Cells are located in water bodies (e.g., lakes, reservoirs, or large rivers)
- Cells are located in urban areas
- Cells are located in areas used for irrigated agriculture
- Cells contain no information relevant to the dataset (e.g. for a streams data layer, areas outside of streams have NoData)
- Area (cells) subject to fire or other disturbance but the post disturbance condition or value is unknown

Intended Purpose:

Through this "metric dictionary," each metric has been defined to help end-users of the data (and for use with any decision support tools) to understand:

- What tier the metric is in (1, 2, or3)
- Data vintage
- The definition meant by a given metric
- The expected use(s) of the metric
- The resolution of the developed data
- The data sources used to derive the metric
- The method of metric derivation
- The root file names

References have been included to help the reader understand potential methods for deriving metrics. It is our hope this information will help people make better use of all the assembled information and how it can best be used with various decision support tools. This dictionary will be updated periodically, as necessary.

Note that all metric data layers have been masked (i.e. blocked out) for open water (lakes, reservoirs) and a selected few have been masked for the urban and agricultural landscape (see the list of operational layers at the end of this document). This is done to avoid confusion with vegetation values coming from urban areas (e.g. city parks) or agricultural areas (e.g. irrigated farm land).

Generating Metrics with the F3 Model

Many metrics related to vegetation structure and composition have been generated using a modeling framework known as **F3** (Huang *et al* 2018). The F3 process, developed by scientists at the US Forest Service Region 5 Mapping and Remote Sensing (MARS) Team, is a collection of algorithms that combine remotely sensed, biophysical setting, climate and Forest Inventory and Analysis (FIA) data. The F3 framework couples **F**IA plot measurements and the **F**orest Vegetation Simulator (FVS) to compute forest structure and biophysical characteristics estimates. The plot-level estimates are then imputed using the **F**astEmap (Field And SatelliTe for Ecosystem MAPping; Huang *et al* 2017) algorithm to produce spatially explicit representations of each calculated metric. The following section is an overview of the general F3 process, and it is highly recommended that interested readers become familiar with the afore-linked scientific articles.

This work was produced with data and the collaboration of the USDA Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis Program.

General F3 Process

The framework for F3 begins with the FIA inventory data which has been pulled from the NIMS Oracle database and ranges from the early 2000s up to 2019 (the most recent collection of FIA plot data due to COVID complications). The inventory data is first filtered and plots which have been disturbed (by fire, insect, harvest) are removed from the pool of available plots prior to being run through FVS. Plots measured prior to 2019 are grown to the concurrent 2019 year through FVS under natural succession conditions (i.e., no management). This allows all data to reflect a single year condition. The multi-temporal scenario projections from FVS provide forest structure and biophysical characteristic estimates which are point specific and joined to a point shapefile representing FIA plot locations. The FastEmap algorithm then extrapolates these point specific forest metrics to spatially contiguous map products based on remote sensing and other auxiliary geospatial data.

The step-by-step FastEmap process starts with the FVS results shapefile and concurrent Landsat 8 data (2019) with cloud and shadow removed. FastEmap begins by extracting the remote sensing (RS) values and environmental properties (i.e., topography, soil, elevation, aspect, slope precipitation, temperature) of the pixel where a FIA plot is located. Next 'virtual plots' are identified that are nearly identical in RS values and environmental properties to the identified plot pixel; the FVS metric measurement from the plot is assigned to these extremely similar pixels and the process is repeated for every field plot. The area is then stratified into different groups which have similar RS values and environmental conditions and the expanded plots (actual and virtual) that fall within a group are identified and weightings calculated. FastEmap uses a stepwise regression analysis to predict the metric measurement and the process is repeated for all stratified groups. Finally, local interpolation and strata median filling are used for those pixels still not imputed. The FastEmap process is run three times, allowing for an average of the three results to be spatially compiled into the final result. Several steps are taken in the processing workflow to ensure FIA plot security is maintained. Among these measures, for metrics provided in the resource kit, rasters were upscaled to 300 m by computing the average or majority value for continuous and discrete metrics, respectively, within a moving 10 x 10 window of 30 m pixels. The following flowchart from the F3 article has been included to help illustrate the full F3 process.

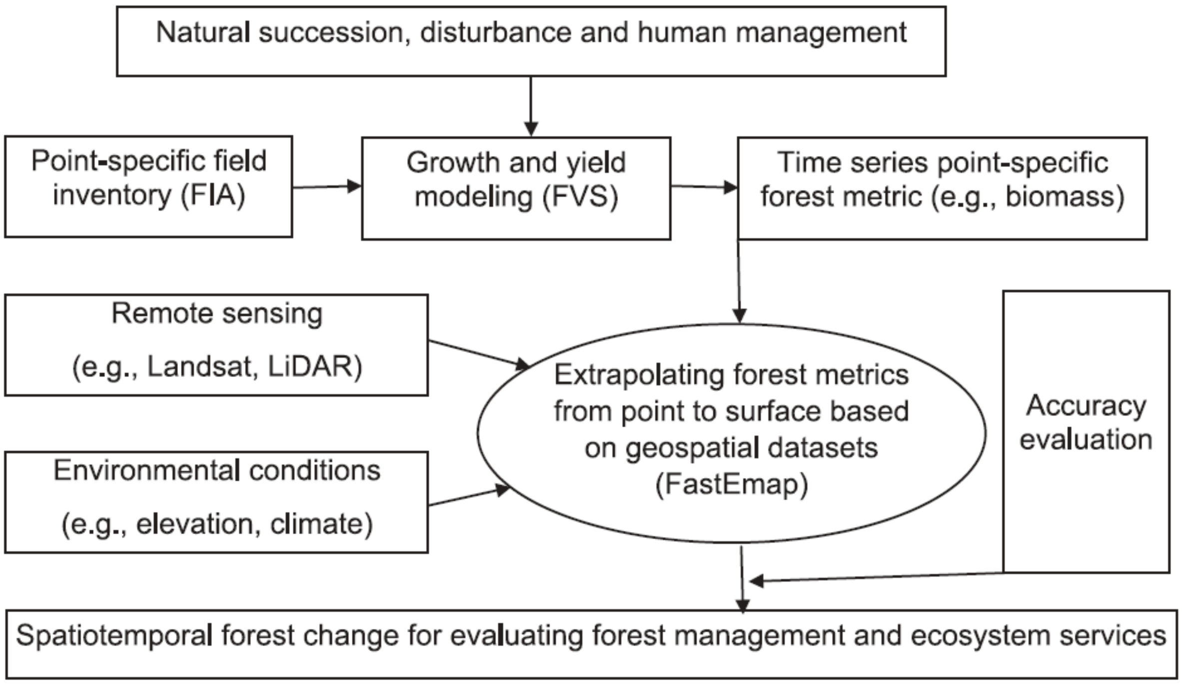

Fig. 1. Flowchart of F^3 modeling framework.

Advantages and Limitations

The advantage of F3 comes from the leveraging of highly detailed information of stand condition, revisited over time in FIA plot data, which in turn drives the FVS natural succession model simulating stand change and extrapolates this point-specific plot information to a landscape level. F3 modeled outputs provide landscape managers information that is "high-detailed, spatially-explicit, multi-temporal, and scenario-comparable" (Huang *et al* 2018).

However, there are important limitations to the F3 data for users to keep in mind. The first limitation is that for this iteration of the SNV RRK, the F3 products are current to 2019 conditions and therefore do not capture recent disturbances (i.e., fire events of 2020 and 2021). To address this limitation, an approach to identify and update these recently disturbed pixels was implemented which incorporates the Ecosystem Disturbance and Recovery Tracker (eDaRT; Koltunov et al. 2020), a Landsat-based high density time series anomaly detection algorithm. (See the next section for additional information.)

Another acknowledged limitation of F3 stems directly from the original FIA plot inputs. FIA plots are only sampled in "forested" conditions, defined as exceeding 10% canopy cover of trees, and therefore are an incomplete representation of reality. The areas that do not meet the definition of forested conditions will not have tree information collected and this directly affects the performance of F3 in non-forested areas that contain trees (such as meadows). To mitigate this type of condition misrepresentation, a meadow mask is applied to the combined averaged data layer during the final processing steps.

While F3 can incorporate management scenarios into the products, it is beyond the scope of this effort, as these data are being produced at the Sierra Nevada range scale and management scenarios are produced at a forest scale or finer. Finally, although F3 products are delivered as 30-meter pixels, the products have been designed for landscape level analyses and as such, analysis at the single pixel scale is not recommended.

Updating F3 Data for Change Events

2019 Data Products

The remote sensing data used for this product are a May-September medoid composite for year 2019 from Landsat; therefore, any actual disturbance (e.g., fire, logging, beetle, and drought) that took place in the latter half of 2019 are not reflected in the F3 product.

2021 Data Products

F3 2019 data products were modeled forward to conditions in 2021 using the Ecosystem Disturbance and Recovery Tracker (eDaRT; Koltunov et al. 2020). The newly developed estimate of fractional canopy cover loss in eDaRT, called Mortality Magnitude Index (MMI) uses anomaly metrics representing normalized statistics of vegetation indices derived from Landsat data at 30m scale (Slaton et al., in prep). MMI was calibrated for drought- and insect-caused tree mortality, but also serves as a reasonable proxy for severity of other forest disturbances, including fire (US Forest Service, 2020). In many cases, MMI values were used to directly adjust F3 metrics from the year 2019 to 2021, while in other cases, additional conversion factors based on published literature were required. The logic and ruleset for adjustments for each metric are provided within the metrics section of this document.

eDaRT disturbance events are attributed with an onset date corresponding to the two-week time period of the first Landsat image in which the disturbance was detected and this sub-annual timing was relied upon for the F3 year 2021 adjustments. First it is important to note that while the F3 2019 composite represents May-September, an image stack medoid for summer months in temperate ecoregions will naturally represent conditions earlier in that time period, before ecosystem disturbances such as fire, insect- and drought-related tree mortality, and restoration activities accumulate over the course of the season. Inspection of the image confirmed that August-September disturbances were not apparent. Therefore, we used disturbances from eDaRT with start dates from August 1, 2019 through November 30, 2021. Some actual disturbances late in that time window may have been omitted, because sufficient subsequent images following a disturbance (i.e. late 2021 or into 2022) are required to confirm events from late 2021.

Air Quality

The goal of healthier forests is aligned with the goal of having healthier air (Cisneros et al., 2014, Long et al., 2018). Forests with sustainable fuel loads create less emissions overall, and support less rapid fire growth, which reduces emissions per day and decreases the chances that smoke from a wildland fire event will create long duration, intense smoke episodes like those we've seen at regional scales during the past decade. Key to supporting the proactive management of smoke and minimization of impacts is a granular understanding at the project scale of where the fuels are, and what potential emissions might occur under wildfire and/or Rx fire scenarios. Those emissions (e.g., from maps like those produced by F3 below) combined with estimates of daily spread can be used to inform operational or scenario-based dispersion modeling (and would be compatible with California's PFIRS smoke management system), which in turn would help fire and air managers better understand where smoke is likely to go, and help inform the public where and when it's likely to occur at potentially unhealthy concentrations.

Tradeoffs between wildfire and Rx fire smoke production (daily, or in total) could be quantified on a first order basis by summing daily or total emissions from high severity vs moderate severity over the area of the respective fire spread polygons. Note that Rx fire smoke impacts are not only different due to per acre differences in emissions, but because the per day emissions can also differ quite substantially. Those emissions numbers could also inform dispersion modeling scenarios showing the relative differences in smoke impacts between wildfire and prescribed scenarios, or even between different wildfire management scenarios.

DESIRED OUTCOME: Emissions from fires are limited to primarily low- and moderate-severity fires in wildland ecosystems. Forests improve air quality by capturing pollutants.

Particulate Matter

Particle pollution represents a main component of wildfire smoke and the principal public health threat. Fine particles (also known as PM2.5)are particles generally 2.5 µm in diameter or smaller and represent a main pollutant emitted from wildfire smoke. Fine particles from wildfire smoke are of greatest health concern.

Potential Total Smoke Production Index

Tier: 1

Data Vintage: 2022

Metric Definition and Relevance: This metric is an index of the potential smoke production (represented by particulate matter that is 2.5 microns or less in diameter, or $PM_{2.5}$) that could be emitted for a given 30-meter pixel under fire weather conditions that produce high severity fire effects. By showing spatial variation in potential smoke emissions under standardized fuel moisture conditions, this index is intended to help identify potential emissions hotpots within a region if a high severity wildfire occurs in the future. It may be useful for regional scale planning and/or prioritization.

However, the actual moistures and fire weather conditions under which these fuels may convert to smoke will vary; therefore, the map does not represent actual smoke production ($PM_{2.5}$ emissions) during an actual fire event. For data users interested in near-term smoke forecasts that reflect the environmental drivers of emissions, project-specific modeling tools are recommended. For example, the BlueSky Playground (https://tools.airfire.org/playground) can tailor model inputs based on the fuel and moisture conditions observed or planned for in the project area of interest.

Potential smore emissions do not consider the probability of a fire or the transport of smoke to more distant locations; they only reflect what would happen locally if a pixel were to burn.

Data Resolution: 30m Raster

Data Units: 0 - 1**,** a unitless number serving as an index; on a per 30-m pixel basis

Creation Method: Potential TOTAL smoke production index is the smoke production expected for a given pixel under severe fire weather conditions. It is based on model outputs from the First Order Fire Effects Model (FOFEM) developed by the U.S. Forest Service (Spatial FOFEM: https://www.firelab.org/project/fofem-fire-effects-model). Key drivers (and model inputs) for this mapped variation are (1) fuel loads spatially extracted from the Landfire FCCS modeled fuelbeds map (LANDFIRE 2022 Update (LF 2.3.0), https://www.landfire.gov/lf_230.php), and (2) fuel moistures, which are assigned to approximate the extremely dry conditions under which high severity fire generally occurs. The data are dimensionless and linearly normalized from 0 to 1 based on the statewide maximum value, with 1 being the maximum $PM_{2.5}$ emissions per 30-m pixel for the given region. Fuels are taken from LANDFIRE LF2022_FCCS_220. Spatial FOFEM was run as implemented in FlamMap 6.2 (https://www.firelab.org/project/flammap).

This index is a unitless number (ranging between 0 and 1) on a per 30-meter pixel basis, which is calculated using the following equation:

Potential Total Smoke Production Index = S_i / (maximum S_i statewide)

where

S_i = high severity PM2.5 emissions value for pixel i

Calculated with SpatialFOFEM (First Order Fire Effects Model), embedded in FlamMap 6.2. Fuels are LCP and FCCS 2022 from LANDFIRE (LCP_LF2022_FBFM40_220_CONUS and LF2022_FCCS_220_CONUS). FOFEM Parameters used for this application are:

Seasonality - (Summer)

Canopy consumption – 39%

Duff moisture – 20%

1 hour fuel moisture – 4%

10-hour fuel moisture – 6%

100-hour fuel moisture – 8%

1000-hour fuel moisture – 8%

Analysis was done at UC Irvine.

Data Source: LANDFIRE FCCS (LANDFIRE Program: Data Products – Fuel – Fuel Characteristic Classification System Fuelbeds) 2022

Rocky Mountain Research Station

https://www.firelab.org/project/fofem-fire-effects-model

File Name: PotentialTotalSmoke_202209.tif

Potential Avoided Smoke Production Index

Tier: 1

Data Vintage: 2022

Metric Definition and Relevance: This is an index of how much *less* smoke (as defined by $PM_{2.5}$ emissions) would be produced from a given pixel by burning under moderate fire weather conditions rather than the extreme conditions that lead to high-severity smoke production. This serves as a proxy for efforts to minimize smoke emissions by allowing a given area to burn under more desirable conditions (e.g., prescribed burning conditions) vs. how it would burn under extreme conditions. Since identical fuelbeds are used as inputs in the high-severity and low-severity model runs, the index does *not* represent the effects of fuel treatments on subsequent wildfire. Rather, this metric represents the maximum potential difference between emissions under high vs. moderate fire weather conditions. Summing these reductions over large areas would be unrealistic because wildland fire burns with a mix of intensities and severities over landscapes, and does not burn everywhere in California, every year.

Wildland fire is often self-limiting in extent. In other words, wildfires may stop spreading when they reach the boundary of a recent burn. Since prescribed fire and managed wildfire can be selected to burn under moderate fire weather conditions, proactive fire use can shift high-severity-type fire emissions to low-severity-type fire emissions.

This metric provides a rough index of the potential fire emissions benefits if a fire is allowed to burn under moderate weather conditions rather than in a wildfire under extreme weather. By showing the spatial variation in this potential benefit, this index is intended to help identify where fire management may have the greatest emissions benefit. It may be useful for regional scale planning and/or prioritization.

It is important to note that not all managed fire will produce an emissions benefit, because wildfire may not have otherwise burned in that location within the lifespan of the managed fire's effects, and the managed fire's footprint may not prevent a subsequent wildfire from burning in the same location. Furthermore, actual weather conditions vary from those used in model inputs. Therefore, the map does not represent actual avoided smoke production ($PM_{2.5}$ emissions) during an actual fire event that may occur in the future. For data users interested in near-term smoke forecasts that reflect the environmental drivers of emissions, project-specific modeling tools are recommended. For example, the BlueSky Playground (https://tools.airfire.org/playground) can tailor model inputs based on the fuel and moisture conditions observed or planned for in the project area of interest.

Potential smoke emissions do not consider the probability of a fire or the transport of smoke to more distant locations; they only reflect what would happen locally if a pixel were to burn.

Data Resolution: 30m Raster

Data Units: 0 - 1, a unitless number serving an an index; on a per 30-m pixel basis

Creation Method: This index a unitless number (ranging between 0 and 1) on a per 30-meter pixel basis, which is calculated using the following equation:

Potential Avoided Smoke Production Index = (D_i for a given pixel) / (the maximum D_i statewide)

where

D_i = the difference in modeled $PM_{2.5}$ emissions between high severity and low severity scenarios for pixel i = (high severity $PM_{2.5}$ emissions scenario for pixel i) – (low severity $PM_{2.5}$ emissions scenario for pixel i)

"High severity $PM_{2.5}$ emissions" were calculated as described for the "POTENTIAL TOTAL SMOKE PRODUCTION INDEX" metric.

Calculated with SpatialFOFEM (First Order Fire Effects Model), embedded in FlamMap 6.2. Fuels are LCP and FCCS 2022 from LANDFIRE (LCP_LF2022_FBFM40_220_CONUS and LF2022_FCCS_220_CONUS). Conditions for Low severity PM 2.5 emissions were calculated for the following settings (FOFEM parameters used for this application):

Seasonality: Spring

Canopy consumption - 5%

Duff moisture - 75%

1 hour fuel moisture - 14%

10-hour fuel moisture - 16%

100-hour fuel moisture - 18%

1000-hour fuel moisture - 25%

Analysis was done at UC Irvine.

Data Source: LANDFIRE FCCS (LANDFIRE Program: Data Products - Fuel - Fuel Characteristic Classification System Fuelbeds) 2022

Rocky Mountain Research Station

https://www.firelab.org/project/fofem-fire-effects-model

File Name: PotentialAvoidedSmoke_202209.tif

Total Fuel Load

See the Total Fuels Exposed to Fire metric within the Fire Dynamics Pillar.

Heavy Fuels

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Emissions (on which the modeled PFIRS and Smoke Spotter smoke plumes are based, and which are generated by the BlueSky Playground) are especially sensitive to changes in the coarse fraction of dead wood in the fuel bed, if those fractions are dry enough to be available. It is therefore important to map with project-scale detail where the heaviest fuels might be, so managers have a good estimate for operational smoke management and scenario planning at their project scale, and where perhaps the standard fuelbeds (and emissions estimates based on them) might be underestimating heat and smoke production that can drive unexpected fire behavior, plume loft, and/or smoke impacts.

Data Resolution: 30m raster

Data Units: Short tons biomass/acre

Creation Method: The F3 model generated several different raster surfaces of fuel loading estimates of the coarse woody debris by non-overlapping size classes; including 1, 10, 100, 1000-hour fuels (FLOAD_1-5). The model also produced estimates for coarse woody debris of heavy fuels by predefined non-overlapping size classes which are greater than the 1000-hour fuel size (>=12"; FLOAD_6-9).

2019 to 2021 Update: No adjustments were made for 2021 due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), fuel values are not represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that heavy fuel values did not change significantly over the course of two years.

This layer is derived from F3 layers (2021) using the following formula:

$$SUM(FLOAD\_5\text{-}9)$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: HeavyFuels_2021_30m.tif

Biodiversity Conservation

The Sierran landscape provides habitat for over 300 species of native vertebrates and thousands of invertebrate species and plants. Management activities over the last century have impacted most species to varying degrees and some have declined significantly in recent decades. Protecting and enhancing native biodiversity has become a management imperative under both federal and state laws and policy. Native plants and animals provide a wide array of benefits to forests and other habitats in the Sierra; they help forests recover after a fire, control flooding and soil erosion, cycle nutrients, and are valued by people recreating in forests. Greater species diversity promotes adaptability and helps ecosystems withstand and recover from disturbance, including those caused by climate change. The Biodiversity Conservation pillar focuses on species diversity, critical habitat for focal species and non-native species distribution.

DESIRED OUTCOME: The network of native species and ecological communities is sufficiently abundant and distributed across the landscape to support and sustain their full suite of ecological and cultural roles.

Focal Species

For specified species listed below within the Focal Species element section of the Biodiversity Conservation pillar, the species should be considered as *Species of Interest*. It is important for the readers to understand, the listed species are not exhaustive, may be an Endangered Species Act (ESA) species, or considered Sensitive Species as they pertain to forest planning. These species are identified based on their sensitivity to impacts from restoration thinning, prescribed fire, and wildfire. The two wildlife species are California spotted owl and fisher. Black oak is an important species for wildlife as well as for tribes.

Pacific Marten Suitable Habitat

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The Pacific martin is a species of special concern, but it is not federally, or state listed at the present time. It is identified as a focal species by Region 5 of the US Forest Service. The Pacific marten is a high elevation, old forest associate that is sensitive to forest management and is an important carnivore in high elevation food webs. This metric evaluates the 1000 ac around each 30m pixel to determine if it meets the minimum habitat requirements to support a territory.

Data Resolution: 30m raster

Data Units: 30m data – Binary, 0 = not suitable, 1 = suitable

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database. Habitat that meets any of the following criteria is considered suitable:

- Suitable foraging vegetation types: WHRTYPE = MRI, RFR, DFR, WTM, LPN, SCN, MHC
- Suitable foraging habitat: size/density classes = 4M, 4D, 5M,5D, 6
- Suitable denning vegetation types: WHRTYPE = MRI, RFR, DFR, LPN, SCN, MHC

- Suitable denning habitat: size/density classes = 4M, 4D, 5M, 5D, 6

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: marten_suitablehabitat.tif

Band-Tailed Pigeon

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The Band-Tailed pigeon is a species of tribal value to California indigenous peoples and has been identified as a focal species for the SNV RRK project. This metric identifies the current distribution and abundance of suitable habitat for band-tailed pigeons. Blocks of habitat of 100 acres or larger, which are considered high value to band-tailed pigeons for reproduction, cover, and feeding are included.

Data Resolution: 30m raster

Data Units: Binary, 0 = not suitable, 1 = suitable

Creation Method: This distribution map was created by identifying pixels which contained high value habitat for band-tailed pigeons in all three categories of life history; reproduction, cover, and feeding within habitat types where they are found. This is based on the ratings for habitat values found in the California Wildlife Habitat Relationships model managed by the California Department of Fish and Wildlife. All pixels that rated high for all three life history categories within a habitat were identified and contiguous blocks of greater than 250 acres were selected and included.

- Suitable vegetation types: WHRTYPE = BOP, BOW, MHW, MHC, MRI, SMC, VOW, WFR
- Suitable high-quality habitat size/density classes by type:
    - BOP = 5M, 5D
    - BOW = 5M, 5D
    - MHW = 4M, 4D, 5P, 5M, 5D
    - MHC = 4M, 4D, 5S, 5P, 5M, 5D
    - MRI = 4M, 4D, 5S, 5P, 5M, 5D
    - SMC = 4M, 4D, 5S, 5P, 5M, 5D, 6
    - WFR = 4M, 4D, 5S, 5P, 5M, 5D, 6

Data Source: California Department of Fish and Wildlife (CDFW) California Wildlife Habitat Relationships (CWHR)

File Name: band_tailed_pigeon_250ac_binary.tif

California Red-legged Frog Habitat Distribution

Tier: 1

Data Vintage: 06/2001

Metric Definition and Relevance: This dataset represents a species habitat distribution map for California Red-legged Frog (*Rana draytonii)* within the conterminous United States (CONUS) based on 2001 ground conditions.

Data Resolution: 30m Raster

Data Units: Binary layer, 1 represents current habitat

Creation Method: This Gap Analysis Project (GAP) habitat map is a prediction of the spatial distribution of suitable environmental and land cover conditions within the United States for the species. Mapped areas represent places where the environment is suitable for the species to occur (i.e. suitable to support one or more life history requirements for breeding, resting, or foraging), while areas not included in the map are those predicted to be unsuitable for the species. While the actual distributions of many species are likely to be habitat limited, suitable habitat will not always be occupied because of population dynamics and species interactions. Furthermore, these maps correspond to midscale characterizations of landscapes, but individual animals may deem areas to be unsuitable because of presence or absence of fine-scale features and characteristics that are not represented in our models (e.g. snags, vernal pools, shrubby undergrowth). These maps are intended to be used at a 1:100,000 or smaller map scale.

This habitat map is created using a deductive model to predict areas suitable for occupation within a species range. The deductive habitat models are built by compiling information on the species' habitat associations and entering it into a relational database. Information is compiled from the best available characterizations of the species' habitat, which included species accounts in books and databases, primary peer-reviewed literature. The literature references for each species are included in the "Species Habitat Model Report" and "Machine Readable Habitat Database Parameters" files attached to each habitat map item in the ScienceBase repository. The compiled habitat information is used by a biologist to determine which of the ecological systems and land use classes represented in the National Gap Analysis Project's (GAP) Land Cover Map Ver. 1.0 the species is associated with.

The maps are generated using a python script that queries the model parameters in the database; reclassifies the GAP Land Cover Ver 1.0 and ancillary data layers within the species' range; and combines the reclassified layers to produce the final 30m resolution habitat map. Map output is, therefore, not only a reflection of the ecological systems that are selected in the habitat model, but also any other constraints in the model that are represented by the ancillary data layers.

Credits: U.S. Geological Survey (USGS) - Gap Analysis Project (GAP), 2018, California Red-legged Frog (*Rana draytonii*) aCRLFx_CONUS_2001v1 Habitat Map: U.S. Geological Survey data release, https://doi.org/10.5066/F7T43RCM.

Data Source: USGS

File Name: california_red_legged_frog_habitat_200106.tif

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: California black oak serves as important wildlife habitat and as a traditional food source for indigenous Californians. The map is intended to be used to inform – and potentially prioritize – management of California black oak stands (*e.g.*, fuels treatments to protect the resource) and to assist those seeking stands for acorn collection (i.e., for reforestation or food).

A satellite-derived map of California black oak (*Quercus kelloggii*; QUKE) stand distribution from a model trained to Landsat imagery.

Data Resolution: 30m raster

Data Units: Value, 0 to 1000

Creation Method: Statistical models were fit to seasonal median Landsat 8 spectral bands 1 – 7 for the period encompassing 2016 – 2020. Training occurrence data spanned the Sierra Nevada RRK project boundary and consisted of 325 30m radius plots assessed via aerial imagery to have ≥ 90% California black oak (QUKE) canopy cover and filtered to exclude plots that experienced > 10% loss of absolute tree canopy cover after the date of the image used to assess QUKE canopy cover (Wang et al. 2022). Training occurrence data were combined with 98,506 pseudo-absence locations. From a candidate set that included multiple model-fitting approaches (e.g., Maxent, Random Forests, LDA) Maxent (default settings, version 3.4.3) was selected for its consistently high out-of-sample predictive performance. Seasonal periods of Landsat imagery were defined as follows: Winter (Jan 1 – March 1), Spring (March 31 – May 20), Summer (June 1 – Aug 18), Fall (Oct 17 – Nov 26). Spatial predictions form the statistical model were masked to exclude agricultural urban areas (FVEG), riparian areas (Abood et al. 2022), meadows (UC Davis & USDA Forest Service 2017), and areas with canopy height < 5 m (Salo Sciences, Spring 2020). Spatial predictions were multiplied by 1000 and rounded to the nearest integer to reduce file size.

Resulting out-of-sample predictive performance was high for delineating areas of ≥ 90% QUKE canopy cover from the broader landscape (AUC = 0.997; mean QUKE cover in sample = 95%). Though the model was trained on plots with ≥ 90% QUKE canopy cover, out-of-sample performance remained relatively high for areas of 50 – 90% QUKE canopy cover (AUC = 0.981; mean QUKE cover in sample = 80%) and areas of 10 – 50% QUKE canopy cover (AUC = 0.959; mean QUKE cover in sample = 34%). The model appears to have moderate skill in predicting continuous QUKE cover – in our sample (biased toward higher QUKE canopy cover plots with mean QUKE cover of 82%) the Spearman's rank correlation coefficient between the model output QUKE score and QUKE canopy cover was 0.54. Notable areas of commission error include certain other deciduous vegetation types, such as aspen.

QUKE Score	Interpretation
0	Very low likelihood of overstory QUKE dominance or very low QUKE overstory cover.
1 – 50	Low likelihood of overstory QUKE dominance or low QUKE overstory cover.
51 – 500	Moderate likelihood of overstory QUKE dominance or moderate QUKE overstory cover.
501 – 1000	High likelihood of overstory QUKE dominance or high QUKE overstory cover.

Data Source:

- Center for Watershed Sciences, UC Davis – see Meadows
- California Forest Observatory (Salo Sciences), 2020

File Name: CA_Black_Oak_Stand_Distribution_2016to2020_30m.tif

---

California Spotted Owl Suitable Habitat

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: California spotted owl is continuously distributed on the western slope of the Sierra and inhabits elevations ranging from roughly 1,000 to over 7,000 feet.t is a Region 5 Forest Service "Sensitive Species" and a "Management Indicator Species" (representing late seral closed canopy coniferous forest). In February of 2023 the U.S. Fish and Wildlife Service issued a proposal to list two distinct population segments (DPSs) of the California spotted owl (*Strix occidentalis occidentalis*) under the Endangered Species Act of 1973, as amended (Act). That proposal is still pending. Although the species is declining throughout much of its range and faces continued threats due to wildfire, habitat loss, and competition from barred owls, the USFWS determined that existing regulatory mechanisms are sufficient (USDI Fish and Wildlife Service 2019). This species is also recognized as a California "Species of Special Concern and a Species of Greatest Conservation Need."

A conservation assessment for California spotted owl was conducted in 2017 (Gutiérrez, Manley, and Stine 2017). This was followed by the development of a conservation strategy to guide habitat management on National Forest System Lands (USDA Forest Service 2019). The conservation strategy for the California spotted owl in the Sierra Nevada aims to balance the need to conserve essential habitat elements around sites occupied by California spotted owls, while simultaneously restoring resilient forest conditions at the landscape scale (USDA Forest Service 2019).

The USDA Forest Service designates a 300-acre protected activity center (PAC) around each known nesting (reproduction) area or activity center. PACs are a USFS land allocation designed to protect and maintain high-quality California spotted owl nesting and roosting habitat around active sites. Territorial owls typically defend a geographic area consistently used for nesting, roosting, and foraging, containing essential habitat for survival and reproduction. The USDA Forest Service calls for an area of 1,000 acres in the central Sierra Nevada around core use areas, including the associated protected activity center, with a minimum of 400 acres of suitable habitat.

Data Resolution: 30m raster

Data Units: Binary, 0 = not suitable, 1 = suitable

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed suitable for the reproduction of that species in the California Wildlife Habitat Relationship database. Habitat which meets the following criteria is considered suitable:

- Suitable vegetation types: WHRTYPE = PPN, SMC, RFR, DFR, MHC, MHW, SMC, WFR, RDW, KMC MRI and BOP
- Suitable foraging habitat: size/density classes = 4M, 4D
- Suitable nesting habitat: size/density classes = 5M, 5D, 6

CWHR high suitability values have been used to create separate data layers which identify suitable nesting and suitable foraging habitat. These data have been combined to create the identified "suitable habitat" layers.

The California spotted owl territory suitability metric ("territory") evaluates the 1000 ac around each 30m pixel to determine if it meets minimum habitat requirements to support a territory. The nesting habitat requirement is 300 ac within a 1000-ac circular area, and is represented by CWHR habitat types 4M, 4D, 5M, 5D, and 6. Foraging habitat requirement was an additional 300 ac (600 total) within the 1000-ac circular area and was represented by CWHR habitat types 3M and 3D, as well as the nesting habitat types.

An additional data layer to identify locations that meet the criteria for a protected activity center (PAC), which is 300 acres of suitable nesting habitat in a contiguous block has been provided with the operational data layers – see PAC layer.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: CSO_suitablehabitat_combined.tif

California Spotted Owl Territory Suitability

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: California spotted owl is continuously distributed on the western slope of the Sierra and inhabits elevations ranging from roughly 1,000 to over 7,000 feet.t is a Region 5 Forest Service "Sensitive Species" and a "Management Indicator Species" (representing late seral closed canopy coniferous forest). In February of 2023 the U.S. Fish and Wildlife Service issued a proposal to list two distinct population segments (DPSs) of the California spotted owl (*Strix occidentalis occidentalis*) under the Endangered Species Act of 1973, as amended (Act). That proposal is still pending.

A conservation assessment for California spotted owl was conducted by Region 5 of the U.S. Forest Service in 2017 (Gutiérrez, Manley, and Stine 2017). This was followed by the development of a conservation strategy to guide habitat management on National Forest System Lands (USDA Forest Service 2019). The conservation strategy for the California spotted owl in the Sierra Nevada aims to balance the need to conserve essential habitat elements around sites occupied by California spotted owls, while simultaneously restoring resilient forest conditions at the landscape scale (USDA Forest Service 2019).

The USDA Forest Service designates a 300-acre protected activity center (PAC) around each known nesting (reproduction) area or activity center. PACs are a USFS land allocation designed to identify, protect, and maintain high-quality California spotted owl nesting and roosting habitat around active sites. Territorial owls typically defend a geographic area consistently used for nesting, roosting, and foraging, containing essential habitat for survival and reproduction. The USDA Forest Service calls for an area of 1,000 acres in the central Sierra Nevada around core use areas, including the associated protected activity center, with a minimum of 400 acres of suitable habitat.

This metric captures the suitability, on a pixel by pixel basis, of a given location to support the needs of a suitable territory for California spotted owls within the 1,000 acres around each pixel.

Data Resolution: 30m raster

Data Units: A range of values that indicates suitability; from -1 meaning not suitable at all, to +1 meaning most suitable.

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed suitable for the reproduction of that species in the California Wildlife Habitat Relationship database. Habitat which meets the following criteria is considered suitable:

- Suitable vegetation types: WHRTYPE = PPN, SMC, RFR, DFR, MHC, MHW, SMC, WFR, RDW, KMC MRI and BOP
- Suitable foraging habitat: size/density classes = 4M, 4D
- Suitable nesting habitat: size/density classes = 5M, 5D, 6

CWHR high suitability values have been used to create separate data layers which identify suitable nesting and suitable foraging habitat. These data have been combined to create the identified “suitable habitat” layers.

The California spotted owl territory suitability metric (“territory”) evaluates the 1000 ac around each 30m pixel to determine if it meets minimum habitat requirements to support a territory. The nesting habitat requirement is 300 ac within a 1000-ac circular area, and is represented by CWHR habitat types 4M, 4D, 5M, 5D, and 6. Foraging habitat requirement was an additional 300 ac (600 total) within the 1000-ac circular area and was represented by CWHR habitat types 3M and 3D, as well as the nesting habitat types.

An additional data layer to identify locations that meet the criteria for a protected activity center (PAC), which is 300 acres of suitable nesting habitat in a contiguous block has been provided with the operational data layers – see PAC layer.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: CSO_territory.tif

Giant Sequoia Stands

Tier: 2

Data Vintage: 2022

Metric Definition and Relevance: The population of giant sequoia (*Sequoiadendron giganteum* [SEGI]) trees is an irreplaceable heritage to be studied, protected, and preserved as it faces increased threats from drought and fire.

Data Resolution: 30m raster

Data Units: Binary, 0/1

Creation Method: The Giant Sequoia grove locations are well described, and their approximate delineations have been used for analysis work for years with the Administrative Grove Boundary (AGB) dataset. These AGB polygons were exaggerated for a variety of reasons and led to erroneous analysis results. An explicit delineation of SEGI populations was needed, especially as the range of the tree is exposed to increased threats instigated by a mega-drought not seen in the region in over a millennia. This dataset addressed that need across the entire range of SEGI.

While some 70+ "Groves" are recognized with the AGB dataset; the historic naming conventions of groves lost to generalization have been reapplied for this work, referencing each distinct area as a "Map Unit." Consider 'Grove' a general term with 'Map Unit' a distinct population distribution for a unique SEGI population. There are 94 Map Units as of 2022 covering 26,270 acres. To create the Map Unit linework, individual SEGI pints were identified, both remotely and in the field, to inform the boundary line work. In the case of the National Park Map Units, the historic Sequoia Tree Inventory (STI) dataset dictated the boundary shape. Elsewhere, the Observed Tree Inventory (OTI) points guided the boundary formation.

For this effort, the giant sequoia stand polygons were subsequently converted to a raster grid at 30m resolution based on existence/non-existence.

Data Source: Region 5, MARS Team

File Name: SEGI_MU_2022_92_1.tif

Mountain Lion Suitable Habitat

Tier: 2

Data vintage: 04/2023

Metric Definition and Relevance: This layer shows highly suitable habitats for the reproduction and feeding of Mountain lion (*Puma concolor*).

Data Resolution: 30m Raster

Data Units: Binary, 0 = not suitable, 1 = suitable

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016

- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: Mountain_Lion_suitable_habitat.tif

Northern Goshawk Suitable Habitat

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The Northern goshawk is a species of special concern to the US Forest Service, but it is not federally, or state listed at the present time and has therefore been identified as a focal species by Region 5 of the US Forest Service. The Northern goshawk is an old forest associate with particular habitat requirements in terms of nest trees, nest stands, and the structure of foraging habitat having open understory conditions to enable foraging maneuvers.

Data Resolution: 30m raster

Data Units: Binary, 0 = not suitable, 1 = suitable

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Suitable habitat for the Northern goshawk is based on CWHR moderate and high suitability habitat for nesting and foraging. CWHR suitability values were used to create a data layer that separately identifies suitable nesting and suitable foraging habitat. Locations that are suitable for both are identified as suitable for nesting (assuming that nesting habitat is more limited). Habitat which meets the following criteria is considered suitable:

- Suitable foraging vegetation types: WHRTYPE = MHW, LPN, MRI, SCN, DFR, MHC, JPN, SMC, EPN, KMC, ADS, PPN, RFR, WFR
- Suitable foraging habitat: size/density classes = 4P, 4S, 4M, 4D, 5P, 5S, 5M, 5D, 6
- Suitable nesting vegetation types: WHRTYPE = MHW, LPN, MRI, SCN, MHC, JPN, SMC, KMC, PPN, RFR, WFR
- Suitable nesting habitat: size/density classes = 4M, 4D, 5P, 5S, 5M, 5D, 6

An additional data layer to identify locations that meet the criteria for a goshawk protected activity center (PAC; 300 acres of suitable nesting habitat in a contiguous block), has been provided with the Operational Data Layers – see PAC layer.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: ng_suitablehabitat_combined.tif

Pacific Fisher Suitable Habitat

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The Pacific fisher population in the southern Sierra is federally listed as a threatened population and resides primarily on National Forest System lands. Habitat management for this species is determined based on a Conservation Strategy developed by the US Forest Service and augmented by a recovery strategy developed by the US Fish and Wildlife Service.

Data Resolution: 30m raster

Data Units: Binary, 0 = not suitable, 1 = suitable

Creation Method: CWHR classifications are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Suitable habitat for the Pacific fisher is based on CWHR moderate and high suitability habitat for denning and foraging. CWHR suitability values were used to create a data layer that separately identifies suitable denning and suitable foraging habitat which meets the following criteria:

- Suitable foraging vegetation types: WHRTYPE = DFR, EPN, JPN, MHC, MHW, MRI, PPN, SMC, WFR, RFR, LPN
- Suitable foraging habitat: size/density classes = 4M, 4D, 5M, 5D, 6
- Suitable denning vegetation types: WHRTYPE = DFR, EPN, JPN, MHC, MHW, MRI, PPN, SMC, WFR
- Suitable denning habitat: size/density classes = 4D, 5M, 5D, 6

The combined (denning and foraging) suitable habitat layer has been further refined and clipped to the U.S. Fish and Wildlife Service species range extent from the Environmental Conservation Online System (ECOS) available at https://ecos.fws.gov/ecp/species/3651#rangeInfo.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: fisher_suitablehabitat_combined.tif

Species Diversity

Species diversity is a function of both the number of different species in the community and their relative abundances. Larger numbers of species and more even abundances of species lead to higher species diversity. Species diversity can be calculated in a variety of ways to represent the type and magnitude of differences among species, their number, and their abundance.

Wildlife Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Native species richness is estimated based on high suitability reproductive habitat for a given species. Reproductive habitat is used to represent suitability because it is critical for species persistence and for most native species it has the most limited requirements. If a habitat is identified as high for a given species, it is considered suitable (1), and habitat identified as moderate, low or not suitable, it is considered unsuitable (0). Species richness values are used as a relative measure of biodiversity value; as such, areas with lower species richness based on these criteria may still have high biodiversity value, but not as high as areas with higher richness values. The number of native species per spatial unit (30m pixel) presented as simply the total number; this can be useful for assessing change in number/composition over space.

Data Resolution: 30m raster

Data Units: Number of species

Creation Method: Generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. CWHR habitat values are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: wildlife_species_richness.tif

Threatened/Endangered Vertebrate Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Native species richness is estimated based on high suitability reproductive habitat for a given species. Reproductive habitat is used to represent suitability because it is critical for species persistence and for most native species it has the most limited requirements. If a habitat is identified as high for a given species, it is considered suitable (1), and habitat identified as moderate, low or not suitable, it is considered unsuitable (0). Species richness values are used as a relative measure of biodiversity value; as such, areas with lower species richness based on these criteria may still have high biodiversity value, but not as high as areas with higher richness values. The total number of federally threatened/endangered native species per spatial unit (30m pixel) can be useful for assessing change in number/composition over space.

Data Resolution: 30m raster

Data Units: Number of species

Creation Method: Generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. CWHR habitat values are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Only species classified in the CWHR database as federally endangered, federally threatened, California endangered, or California threatened have been included in the species richness count for this layer.

2019 to 2021 Update: Adjustments for 2021 canopy cover and size class were made and then integrated to represent CWHR habitat attributes – see CWHR section below for adjustment details.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: t_e_species_richness.tif

Forest Raptors Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Native species richness is estimated based on high suitability reproductive habitat for a given species. Reproductive habitat is used to represent suitability because it is critical for species persistence and for most native species it has the most limited requirements. If a habitat is identified as high for a given species, it is considered suitable (1), and habitat identified as moderate, low or not suitable, it is considered unsuitable (0). Species richness values are used as a relative measure of biodiversity value; as such, areas with lower species richness based on these criteria may still have high biodiversity value, but not as high as areas with higher richness values. The total number of forest raptors native species per spatial unit (30m pixel) can be useful for assessing change in number/composition over space.

Data Resolution: 30m Raster

Data Units: Number of species

Creation Method: Generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. CWHR habitat values are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Only raptor species that are associated with forest habitats have been included in the species richness count for this layer. The raptors included in this layer are Bald Eagle, California Spotted Owl, Cooper'S Hawk, Great-Horned Owl, Merlin, Northern Goshawk, Northern Spotted Owl, Osprey, Peregrine Falcon, Red-Shouldered Hawk, RedTailed Hawk, Screech Owl and Sharp-Shinned Hawk.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: forest_raptors_species_richness.tif

Open Habitat Raptors Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Native species richness is estimated based on high suitability reproductive habitat for a given species. Reproductive habitat is used to represent suitability because it is critical for species persistence and for most native species it has the most limited requirements. If a habitat is identified as high for a given species, it is considered suitable (1), and habitat identified as moderate, low or not suitable, it is considered unsuitable (0). Species richness values are used as a relative measure of biodiversity value; as such, areas with lower species richness based on these criteria may still have high biodiversity value, but not as high as areas with higher richness values. The total number of open habitat raptors native species per spatial unit (30m pixel) can be useful for assessing change in number/composition over space.

Data Resolution: 30m Raster

Data Units: Number of species

Creation Method: Generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. CWHR habitat values are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Only raptor species that are associated with open habitats have been included in the species richness count for this layer. The raptors included in this layer are American Kestrel, Barn Owl, Burrowing Owl, Ferruginous Hawk, Golden Eagle, Long-Eared Owl, Northern Harrier, Prairie Falcon, Rough-Legged Hawk, Short-Eared Owl, Swainson'S Hawk, Turkey Vulture, White-Tailed Kite, California Condor and Great Grey Owl.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: open_forest_raptors_species_richness.tif

Hummingbirds Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Native species richness is estimated based on high suitability reproductive habitat for a given species. Reproductive habitat is used to represent suitability because it is critical for species persistence and for most native species it has the most limited requirements. If a habitat is identified as high for a given species, it is considered suitable (1), and habitat identified as moderate, low or not suitable, it is considered unsuitable (0). Species richness values are used as a relative measure of biodiversity value; as such, areas with lower species richness based on these criteria may still have high biodiversity value, but not as high as areas with higher richness values. The total number of hummingbird native species per spatial unit (30m pixel) can be useful for assessing change in number/composition over space.

Data Resolution: 30m Raster

Data Units: Number of species

Creation Method: Generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. CWHR habitat values are based on a combination of the F3 model for canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with the National Land Cover Database (NLCD) and CALVEG type to include a variety of tree, shrub, grassland, and water dominated habitats. Species are considered present, and habitats considered suitable for each 30m cell for which the canopy cover-size-vegetation combination have been deemed highly suitable for the reproduction of that species in the California Wildlife Habitat Relationship database.

Only hummingbird species have been included in the species richness count for this layer.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016

- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: hummingbirds_species_richness.tif

Beta Diversity

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The number of species that are not the same in two different environments; functional groups and vegetation communities. Beta diversity is a valuable complement to species richness due to its ability to link local-scale changes in species occurrence to landscape-scale shifts in patterns of species composition. Beta diversity measures changes in species composition by comparing species richness and species presence in one locality to all localities within a specified neighborhood size or among specified areas of interest. Localities exhibiting high beta diversity are distinctly unique in terms of species composition as compared to other localities used for comparison. Unlike species richness, beta diversity provides a measure of species composition that can be used to help identify localities which may harbor rare species, localities which could be sources for landscape-level diversity, and regions of either high heterogeneity or homogeneity. Calculated through time, beta diversity can also detect trends in diversity (i.e., loss or gain of heterogeneity among sites) or detect areas in which species composition changes very little.

Data Resolution: 30m raster

Data Units: Sørensen index, 0 to 1

Creation Method: This has been generated using the California Wildlife Habitat Relationships model developed and managed by the California Department of Fish and Wildlife. The beta diversity index used is the Sørensen index. It is an occurrence-based measure of dissimilarity between species composition of two communities, one at the pixel scale and the other across all the other pixels within the associated 3,000m window. It is calculated as the sum of the number of species in each community, divided by two-times the number of species common to both communities plus the sum of the number of species in each community.

$$DSC = (S_1+S_2)/2c+S_1+S_2$$

Where c = species in common, S_1 = species in community 1, and S_2 = species in community 2.

Larger values represent greater differences among the two communities, and therefore greater beta diversity.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: beta_diversity_30m.tif

Community Integrity

The ability of communities to adapt to changing ecological, social, and economic conditions. This entails the capability of an ecological system to sustain a community of organisms that retains the pre-settlement species composition, diversity, and functional organization of natural habitats within a region.

Functional Group Species Richness

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Functional groups are sets of species that share life history characteristics that perform particular functions within an ecosystem. The six functional groups are represented and include a range of trophic levels and ecosystem services. A primary consideration in management is to maintain conditions, adapt to changing conditions and transition to alternate but still productive conditions over time. The maintenance of ecosystem services is a primary concern with climate change.

Data Resolution: 30m raster

Data Units: Number of species

Creation Method: Species list created from CWHR is divided into six functional groups based on The Sierran All Species Information (SASI) database. The SASI database represents a combination of fields populated from the literature and fields populated from questionnaires distributed to individuals with expertise on particular Sierran taxa. The six functional groups include herbivores, predators, insectivores, soil aerators, seed/spore dispersers and cavity nesters/excavators. The diversity of each functional group is first determined by the number of species for which a given location provides high suitability reproductive habitat (as per species richness calculations). Target conditions can be generated based on percentiles of functional group richness across all patches, so that the 90th percentile or higher is considered in target conditions and the 10th percentile or below is considered to be in a fully departed condition.

Data Source:

- Forest type designation (FORTYPE) from Forest Vegetation Simulator (FVS) F3; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- California Department of Fish and Wildlife CWHR version 9.0 (CDFW); 2014

File Name: cavity_nesters_excavators_species_richness.tif; herbivores_species_richness.tif; insectivores_species_richness.tif; predators_species_richness.tif; seed_spore_dispersers_species_richness.tif; soil_aerators_species_richness.tif

Habitat Connectivity

Tier: 1

Data Vintage: 2019

Metric Definition and Relevance: The Terrestrial Connectivity dataset is one of the four key components of the California Department of Fish and Wildlife's (CDFW) Areas of Conservation Emphasis (ACE) suite of terrestrial conservation information. The dataset summarizes the relative ability of a species to move across the landscape between patches of suitable habitat. It shows a compilation of linkages, corridors, and natural landscape blocks identified in statewide and regional connectivity studies. Each hexagon (2.5 mi^2) is ranked into one of the following categories based on the identification of corridors and linkages in statewide, regional, and species-movement studies:

- 5: *Irreplicable and Essential Corridors* – The Nature Conservancy's (TNC) Omniscape model identifies channelized areas and priority species movement corridors. The mapped channelized areas are those areas where surrounding land use and barriers are expected to funnel, or concentrate, animal movement. These areas may represent the last available connection(s) between two areas, making them high priority for conservation.
- 4: *Conservation Planning Linkages* – Habitat connectivity linkages are often based on species-specific models and represent the best connections between core natural areas to maintain habitat connectivity. Linkages have more implementation flexibility than irreplaceable and essential corridors; any linkage areas not included in rank 5 are included here.
- 3: *Connections with Implementation Flexibility* – Areas identified as having connectivity importance but not identified as channelized areas, species corridors or habitat linkage at this time. Future changes in surrounding land use or regional specific information may alter the connectivity rank. Included in this category are areas mapped in the TNC Omniscape study as 'intensified', core habitat areas, and areas on the periphery of mapped habitat linkages.
- 2: *Large Natural Habitat Areas* – Large blocks of natural habitat (> 2000 acres) where connectivity is generally intact. This includes natural landscape blocks from the 2010 CEHC and updated with the 2016 Statewide Intactness dataset. Areas mapped as CEHC NLB and not included in the previous ranks, are included here.
- 1: *Limited Connectivity Opportunity* – Areas where land use may limit options for providing connectivity (e.g., agriculture, urban) or no connectivity importance has been identified in models. Includes lakes. Some DOD lands are also in this category because they have been excluded from models due to lack of conservation opportunity, although they may provide important connectivity habitat.

Data Resolution: 30m raster

Data Units: Categorical; 5 (listed above)

Creation Method: Developed by CDFW, the Terrestrial Connectivity dataset summarizes information on terrestrial connectivity by ACE hexagon (2.5 mi^2) including the presence of mapped corridors or linkages and the juxtaposition to large, contiguous, natural areas. This dataset was developed to support conservation planning efforts by allowing the user to spatially evaluate the relative contribution of an area to terrestrial connectivity based on the results of statewide, regional, and other connectivity analyses. This map builds on the 2010 California Essential Habitat Connectivity (CEHC) map, based on guidance given in the 2010 CEHC report. The data are summarized by ACE hexagon.

The ACE Terrestrial Connectivity polygon, clipped to the SNV RRK project boundary, has been converted to 30m Raster and the connectivity description attribute (CnctDesc) is classified into the five connectivity ranks (detailed above). The ACE Terrestrial Connectivity raster was then combined with eDaRT Mortality Magnitude Index to flag disturbance events occurring from 2019 – 2021. The MMI disturbance intensity estimated the canopy cover loss (as % of each 30 m pixel) which has then been binned into four classifications:

- *Minimal/None* = 0-10% canopy cover loss
- *Low* = 10-40% canopy cover loss
- *Moderate* = 40-70% canopy cover loss
- *High* = 70-100% canopy cover loss

Data Source:

- California Department of Fish and Wildlife; Terrestrial Connectivity, Areas of Conservation Emphasis (ACE), version 3.1 last updated 08/21/2019
- eDaRT MMI disturbance 2019-2021; MMI2019-21

File Name: HabitatConnectivity_201908.tif

Present Day Connectivity in California (Omniscape)

Tier: 1

Data Vintage: last updated 01/2023

Metric Definition and Relevance: This data represents a wall-to-wall characterization of regional habitat connectivity potential in California for plant and animal species whose movement is inhibited by developed or agricultural land uses.

This model of present-day connectivity assumes there will be more 'current flow', representing wildlife movement, coming from and going to areas that are less modified. Wildlife may encounter barriers and land uses that are not conducive to movement en route. They may avoid moving through these areas entirely or these areas will increase their risk of harm. Land use, energy infrastructure, roads, and night lights are some of the factors that affect the 'resistance' to movement in this analysis.

Present Day Connectivity is partitioned into 11 classes (and the code used in the data):

1) 3 - Land use may restrict movement:
2) 4 - Permeable lands that contribute little to regional connectivity
3) 19 - Impeded
4) 25 - Diffuse - Med
5) 29 - Diffuse - High
6) 31 - Intensified - Low
7) 35 - Intensified - Med
8) 39 - Intensified - High
9) 41 - Channelized - Low
10) 45 - Channelized - Med
11) 49 - Channelized - High

Connectivity classes are assembled into categories based on whether an area had more or less flow than would be expected in the absence of barriers. For example, when animal movement is restricted by surrounding land uses, it channelizes into a single movement pathway, or a linkage. These **Intensified** and **Channelized** linkages are areas with more flow and far more flow, respectively, than would be expected in the absence of nearby barriers to movement. **Diffuse** connectivity areas are broadly, permeable areas with as much flow as is expected. Roads and intensive development can cause complete or partial barriers to animal movement, impeding their ability to traverse the landscape. **Impeded** areas are areas where there is less flow than is expected.

The Omniscape output 'current flow' was classified into high, medium and low classes and further categorized by the amount of flow compared to what would be expected in the absence of barriers. The 'Channelized' class has 1.7 times more flow than expected in the absence of barriers and represents the last remaining natural pathway through a modified landscape. The 'Intensified' class has 1.3-1.7 times more flow than expected and represents areas where there are a few remaining natural pathways. The ‘Diffuse’ class has as much flow as expected and represents lands that have many or unlimited movement options.

Data Resolution: 30m Raster

Data Units: Categorical; 11 (listed above)

Creation Method: The approach uses Omniscape, a modified version of Circuitscape (www.circuitscape.org/) with a moving-window algorithm, to quantify ecological flow (potential connectivity) among all pixels within a 50km radius. Circuitscape treats landscapes as resistive surfaces, where high-quality movement habitat has low resistance and barriers have high resistance. The algorithm incorporates all possible pathways between movement sources and destinations and identifies areas of high flow via low-resistance routes, i.e., routes presenting relatively low movement difficulty because of lower human modification, and thus mortality risk.

Data Source: The Nature Conservancy (TNC) Omniscape

c.k.stanley@tnc.org

The Nature Conservancy: A World Where People & Nature Thrive

File Name: PresentDayConnectivity_Omniscape_202301.tif

Carbon Sequestration

Forests play an important role in mitigating climate by sequestering and storing large amounts of carbon. However, forests are at risk of losing carbon because of rates of decay and disturbance, especially with high severity wildfires. Knowing where carbon exists provides a context for where changes in forest conditions will have the greatest impact on carbon storage and sequestration objectives.

DESIRED OUTCOME: Carbon sequestration is enhanced in a stable and sustainable manner that yields multiple ecological and social benefits.

Note that all values for carbon have been expressed in Mg C/ha, the international standard for how carbon is measured. If needed, to convert back to the native short tons per acre, divide the Mg/ha by 2.2417023114334.

Carbon Storage

Carbon storage in forest biomass is an essential attribute of stable forest ecosystems and a key link in the global carbon cycle. After carbon dioxide is converted into organic matter by photosynthesis, carbon is stored in forests for a period of time before it is ultimately returned to the atmosphere through respiration and decomposition or disturbance (e.g., fire). A substantial pool of carbon is stored in woody biomass (roots, trunks, branches). Another portion eventually ends up as organic matter in forest floor litter and in soils. Soil carbon does not change very quickly and is difficult to measure directly.

Total Carbon (F3)

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Identifying ecosystem carbon is essential to land managers and the Total Carbon (F3) metric provides an estimate of the amount of existing carbon and its location on California’s landscape. The metric also provides context for the other metrics used to quantify carbon sequestration. For example, instability or lack of forest resilience, if there wasn't much carbon in the first places, would be of lesser concern than if there were a lot of carbon, all other things being equal.

Data Resolution: 30m raster

Data Units: Mg C/ha

Creation Method: The F3 model generated multiple raster surfaces from the Fire and Fuels Extension of the FVS Carbon Report. These raster surfaces estimated the total aboveground live trees, including stems, branches and foliage (not including roots) to provide the Tons C per acre (Abovegroun); the belowground live tree roots (Belowgroun) and belowground roots of dead and cut trees (Belowgro_1); standing dead trees for all size classes including stems, branches, and foliage still present but not including roots (Standing_D); forest down dead wood, regardless of size (Forest_Dow); forest floor litter and duff (Forest_Flo); and the herbs and shrubs (Forest_Shr). Conversion from short tons per acre (the default F3 output units) to Mg/ha requires multiplication by 2.2417023114334.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. Values for the total aboveground live tree carbon raster (Abovegroun) and for the belowground live tree roots carbon raster (Belowgroun) were adjusted for 2021 following the same procedure using eDaRT MMI. MMI values for canopy cover loss were used as a direct proxy to estimate Carbon loss, following the formula:

$$2021\ Abovegroun = 2019\ Abovegroun - (2019\ Abovegroun * MMI/100)$$

The assumption of direct correlation between canopy cover and Carbon should be viewed with caution.

The 2021 values for the standing dead trees raster (Standing_D) and for the belowground roots of dead and cut trees raster (Belowgro_1) were adjusted in a similar procedure:

- Standing_D: The difference between 2019 and 2021 live volume (as estimated using eDaRT MMI) was converted to short tons/acre using a conversion factor of 32.1 cubic feet/ton and the result was summed with 2019 standing dead.
- Belowgro_1: The difference between 2019 and 2021 belowground live tree roots (as estimated using eDaRT MMI) was summed with 2019 belowground roots of dead and cut trees.

No adjustments were made for 2021 (Forest_Dow, Forest_Flo, Forest_Shr) due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), raster values are not represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that raster values did not change significantly over the course of two years.

This layer for the Total Carbon metric is derived from F3 layers (2021) using the following formula:

$$[sum(Abovegroun, Belowgroun, Belowgro\_1, Standing\_D, Forest\_Dow, Forest\_Flo, Forest\_Shr)]*2.2417023114334$$

In cases where any individual input to the formula is NULL, the resulting sum cannot be computed and is therefore also NULL.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: F3_TotalCarbon_2021_30m.tif

Total Aboveground Carbon

Tier: 1

Data Vintage: 09/2020

Metric Definition and Relevance: Identifying ecosystem carbon is essential to land managers and the Total Aboveground Carbon metric provides an estimate of the amount of existing carbon and its location on California's landscape. The metric also serves to provide context for the other metrics used to quantify carbon sequestration. For example, instability or lack of resilience in forests with low total aboveground carbon would be of less concern than the same degree of instability in a forest that has large total aboveground carbon.

Data Resolution: 30m Raster

Data Units: Grams dry matter/m2

Creation Method: The Center for Ecosystem Climate Solutions (CECS) DataEngine model tracks monthly carbon in multiple pools from 1986 to 2021. The carbon components are initialized with eMapR (see Additional Resources) observations for the early Landsat era; the model then runs freely based on Landsat and other observations. Disturbances and disturbance intensity are tracked annually by Landsat (see other metrics developed by CECS) and used to quantitatively transfer or combust pools. The model allocates and turns over material based on allometry scaling theory, as adjusted by observational data sets. Aboveground pools (live tree, live shrubs and dead material) are summed for September of 2020.

CECS data that reflect landscape changes resulting from disturbances require 6 to 12 months of Landsat observations **after a given year that included major disturbances (such as a high severity wildfire)** to fully quantify that disturbance. CECS data that reflect disturbance, such as this data layer, are therefore available **through water year 2020 (i.e. through September 2020)**.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: CStocks_Total_Above_202009.tif

Aboveground Live Tree Carbon (F3)

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: A recent paper (Bernal et al., 2022), suggests that due to drought/temps expected beyond 2040, the Sierra Nevada may not be able to support carbon loads of aboveground live trees over 20 Mg C/ha (note that they report biomass values, not carbon values). Carbon values are generally assumed to be half of biomass (See CAL FIRE's "AB 1504" methodology, Christensen et al., 2019).

Data Resolution: 30m raster

Data Units: Mg C/ha

Creation Method: The F3 model generated a raster surface from the Fire and Fuels Extension of the FVS Carbon Report to estimate the total aboveground live trees, including stems, branches, and foliage but not including roots (Abovegroun), to provide the Tons C per acre. Conversion from short tons per acre (the default F3 output units) to Mg/ha requires multiplication by 2.2417023114334.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate Carbon loss, following the formula:

$$2021\ Abovegroun = 2019\ Abovegroun - (2019\ Abovegroun * MMI/100)$$

The assumption of direct correlation between canopy cover and Carbon should be viewed with caution.

This layer for Aboveground Live Tree Carbon metric is derived from F3 layers (2021) using the following formula:

$$[Abovegroun]*2.2417023114334]$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: F3_AbovegroundLiveTreeCarbon_2021.tif

Carbon Stability

Carbon stability is an important feature in carbon sequestration calculations because carbon turnover – high levels of loss, even if followed by high rates of sequestration – are not as ecologically beneficial as high residency rates for carbon and larger pool values, particularly when stored in large live trees which have many other ecological benefits. The carbon in dead biomass is considered a more unstable component of the carbon pool itself, and a potential destabilizing factor for the live carbon pool in fire-adapted forest ecosystems, especially where it exceeds certain thresholds (e.g., over 46 Mg (total biomass)/ha, Stephens et al., 2022).

Large Tree Carbon

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Large trees in this metric were calculated as the sum of branch and stemwood plus foliage for trees over 20 inches in diameter. This is intended to represent the most stable (possibly other than soil) component of the carbon pool, and can be an indicator of the carbon stock's resilience/stability. For this metric, higher values generally indicate more stability, and upward trends in this value may be interpreted as generally increasing resilience of the aboveground C pool.

Data Resolution: 30m raster

Data Units: Mg C/ha

Creation Method: The F3 model generated several different raster surfaces to estimate the biomass of stemwood in non-overlapping predefined size classes (BMSTM_x) and for the branchwood, foliage, and the unmerchantable portion of stemwood above 4" in the same non-overlapping predefined size classes (BMCWN_x).

A recent paper (Bernal et al., 2022), suggests that due to drought/temps expected beyond 2040, the Sierra Nevada may not be able to support carbon loads of aboveground live trees over 20 Mg C/ha (note that they report biomass values, not carbon values). Carbon values are generally assumed to be half of biomass (See CAL FIRE's "AB 1504" methodology, Christensen et al., 2019). Conversion from short tons per acre (the default F3 output units) to Mg/ha requires multiplication by 2.2417023114334.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss, following the formula:

$$2021\ BMCWN\_x = 2019\ BMCWN\_x - (2019\ BMCWN\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss as estimated using eDaRT MMI was equitably distributed among the predefined size classes may result in over- or under-estimates of actual large tree biomass, depending on location.

Values for each of the non-overlapping, predefined, large tree size class for stemwood (BMSTM_x) rasters and for branchwood, foliage, and unmerchantable portion of stemwood above 4” (BMCWN_x) rasters were adjusted for 2021 following the same procedure using eDaRT MMI.

This layer for the Large Tree Carbon metric is derived from F3 layers (2021) using the following formula:

$$[(sum(BMCWN\_25, BMCWN\_35, BMCWN\_40, BMSTM\_25, BMSTM\_35, BMSTM\_40)/2)* 2.2417023114334]$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: LargeTreeCarbon_2021.tif

Dead Carbon

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Dead carbon includes dead and down (litter, duff, fine, coarse, and heavy fuels, including 1000+ hour logs) which are inherently unstable due to prevailing fire and decay processes, and a destabilizing factor in the fire-adapted forests of the Sierra to the extent that they contribute to uncharacteristic fire behavior. In addition to that dead carbon, this metric includes the carbon from the canopies of small trees, which is readily released during fire (specifically, trees less than 10 inches in diameter). Standing dead carbon is also included, representing the slower leak from the landscape carbon stock. As a result, this metric is a proxy for unstable carbon: fire liable carbon on the landscape which is more vulnerable to combustion.

Data Resolution: 30m raster

Data Units: Mg C/ha

Creation Method: The F3 model generated several different raster surfaces in non-overlapping predefined size classes to estimate the small size live tree (those <10” DBH) branchwood and foliage plus unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x), plus the standing dead estimates for all size classes (including stems, branches, and foliage still present) from the FVS Fire and Fuels extension carbon report (Standing_D). The model also generated several raster surfaces of fuel loading estimates of the coarse woody debris by non-overlapping predefined size classes: including 1, 10, 100, and 1000-hour fuels (FLOAD_1-5); and estimates for coarse woody debris of heavy fuels by non-overlapping predefined size classes greater than the 1000-hour fuel sizes (>=6” and <8”; FLOAD_6-9) and for litter and duff.

A recent paper (Bernal et al., 2022), suggests that due to drought/temps expected beyond 2040, the Sierra Nevada may not be able to support carbon loads of aboveground live trees over 20 Mg C/ha (note that they report biomass values, not carbon values). Carbon values are generally assumed to be half of biomass (See CAL FIRE's "AB 1504" methodology, Christensen et al., 2019). Conversion from short tons per acre (the default F3 output units) to Mg/ha requires multiplication by 2.2417023114334.

2019 to 2021 Update: The 2021 values described below for Total Dead/Down Fuels and for Standing Dead and Ladder Fuels, were summed and converted to Mg C/ha to derive this metric.

No adjustments were made for 2021 to the Total Dead/Down Fuels (FLOAD_x, LITTER, DUFF), due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), total dead/down fuel values are not represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that total dead/down fuels did not change significantly over the course of two years.

Values for 2021 Standing Dead and Ladder Fuels (Standing_D, BMCWN_x) were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss, following the formula:

$$2021\ BMCWN\_x\ = 2019\ BMCWN\_x\ - (2019\ BMCWN\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree biomass, depending on location.

Adjustments for the standing dead trees raster (Standing_D) took the difference between 2019 and 2021 live volume (as estimated using MMI) converted to short tons/acre using a conversion factor of 32.1 cubic feet/ton and the result was summed with 2019 standing dead.

Values of undisturbed areas of Total Dead/Down Fuels (FLOAD_x, LITTER, DUFF) were added to the non-overlapping predefined size classes for the small size live trees (<10" DBH) branchwood and foliage plus unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x), which had been adjusted for 2021 using MMI percent adjustments. This total biomass was halved converting to carbon values and added to the adjusted standing dead and the result converted to Mg C/ha.

This layer for the Dead Carbon metric is derived from F3 layers (2021) using the following formula:

$$[(sum(FLOAD\_1\text{-}9, LITTER, DUFF, BMCWN\_0, BMCWN\_2, BMCWN\_7)/2) + Standing\_D] * 2.2417023114334$$

In cases where any individual input to the formula is NULL, the resulting sum cannot be computed and is therefore also NULL.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: DeadCarbon_2021.tif

Tier: 1

Data Vintage: 09/2020

Metric Definition and Relevance: The average lifetime of aboveground live and dead carbon in years. Locations where the lifetime or turnover time is longer have more carbon in more stable pools, such as large trees or large coarse woody debris. Locations where the lifetime or turnover time is shorter have more carbon in labile pools, such as live or dead leaves.

Data Resolution: 30m Raster

Data Units: Years

Creation Method: Calculated from the ratio of total aboveground carbon and annual decomposition. Aboveground carbon and annual decomposition are both calculated for 2020 from a Landsat-driven pools and fluxes model, as described for the total aboveground carbon product. Aboveground turnover time does not currently account for carbon losses and removals with combustion or harvest.

CECS data that reflect landscape changes resulting from disturbances require 6 to 12 months of Landsat observations **after a given year that included major disturbances (such as a high severity wildfire)** to fully quantify that disturbance. CECS data that reflect disturbance, such as this data layer, are therefore available **through water year 2020 (i.e. through September 2020)**.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: CStocks_Turnovertime_202009.tif

Economic Diversity

Economic Diversity increases business opportunities that provide regional economic vitality and additional benefits to rural and vulnerable populations. Ecosystem services and forest products provide a foundation for many local and regional economic activities and employment opportunities. Forest management should support a sustainable natural resource-based economy.

DESIRED OUTCOME: Forest management and outdoor activities support a sustainable, natural-resource-based economy, particularly in rural communities.

Wood Product Industry

The wood product industry plays an important role in the Sierra Nevada social and ecological realm. The industry provides jobs, income, and local wood products from natural resources as well as being an integral player in managing ecosystems. Restoration activities depend on the wood product industry to be involved in the removal of fuels to appropriate processing facilities as opposed to leaving materials as additional fuel on the landscape.

Sawtimber

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: This metric expresses the amount of total existing, aboveground, live tree stem biomass measured in dry weight tons per acre. This metric can be used to assess the sawtimber volume present at the 30m cell level.

Data Resolution: 30m raster

Data Units: Dry weight tons/acre

Creation Method: The F3 model generated raster surfaces to provide an estimate of the total aboveground live tree stem biomass (ABGDLVSM).

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss, using the formula:

$$2021\ ABGDLVSM = 2019\ ABGDLVSM - (2019\ ABGDLVSM * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022).

Data Source: F3 data outputs, Region 5, MARS Team

File Name: ABGDLVSM_2021_30m.tif

Biomass

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: This metric expresses the total amount of existing biomass volume (measured in dry weight tons per acre) from all live tree crowns (branchwood and foliage) and the tree stems less than 10” dbh. This metric can be used to assess the volume of biomass present at the 30m cell level. It is recognized in some forest types, shrub biomass can be a significant contributor to the total biomass, however due to the aforementioned limitations of the F3 model, the shrub component has not been included.

Data Resolution: 30m raster

Data Units: Dry weight tons/acre

Creation Method: The F3 model generated several raster surfaces to provide an estimate of the total aboveground live tree crown (including foliage) biomass for all trees (ABGDLVBR) and estimates of the tree stem biomass of live small trees (BMSTM; <10” dbh). Since the F3 model data is driven by FIA plot data (which is an incomplete source for shrub metrics), the shrub biomass cannot currently be generated.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. Values for each non-overlapping predefined small tree size class for stemwood biomass (BMSTM_x) raster and for the total aboveground live tree crown biomass for all trees (ABGDLVBR) raster were adjusted for 2021 following the same procedure using eDaRT MMI. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss using the MMI percent adjustments, e.g.:

$$2021\ BMSTM\_x = 2019\ BMSTM\_x - (2019\ BMSTM\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among predefined size classes may result in over- or under-estimates of actual small tree stem biomass, depending on location.

This layer for the available Biomass metric is derived from F3 layers (2021) using the following formula:

$$sum(ABGDLVBR, BMSTM\_0, BMSTM\_2, BMSTM\_7)$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: AvailableBiomass_2021.tif

Cost of Potential Treatments

Tier: 2

Data Vintage: 2022

Metric Definition and Relevance: This metric is dependent on predefined treatments or silvicultural prescriptions, which are best generated at the local and/or project level. The cost to perform each treatment depends on a defined prescription and should consider an array of factors including the spatial juxtaposition of the resources and infrastructure, as well as the location of the saw timber and biomass processing plants.

Treatment cost calculations take into consideration the multiple costs necessary to move material from the forest harvest site to a processing location (sawmill or biomass facility) and includes the costs of felling, processing, skidding and hauling:

- costs to move material along different types of roads (i.e., dirt, paved, highways, etc.)
- across barriers (i.e., water courses)
- operational costs
- machine costs
- speed of moving material across the landscape.

Cost values have been broken down into the costs to move either biomass or sawlogs.

Data Resolution: 30m raster

Data Units: $/ton for operation costs and $/acre for prescribed fire and hand treatments

Creation Method: The methods are based on the "RMRS Raster Utility and Function Modeling" and the "Delivered Cost Modeling" approaches developed by John Hogland at the Rocky Mountain Research Station. Using a series of sliders that define various rates for multiple harvesting system and then running the delivered cost model. Within the modeling, the following analyses will be performed:

1. Subset and attribute OSM roads with speed based on criteria in Table 1.
2. Create barrier to offroad motion for off road analysis using a subset of OSM streams, water bodies, interstates, and highways.

3. Estimate potential on road and offroad cost surfaces for each harvesting system using interactive sliders based on the criteria in Table 2.
4. Create felling and processing surfaces and add potential costs.
5. Specify where harvesting systems occur and subset system costs to those locations.
6. Create final spatial representation of the potential cost to treat each raster cell on a dollar per CCF basis.
7. Save final raster surfaces.

The data has been extracted from open street maps and USFS 3dep and consist of base Raster and Vector datasets that have been used throughout the study area:

- Elevation (raster): elevation surface units meters (3dep)
- Roads (vector): Open Street Map roads based on Tiger Lines (OSM)
- Streams (vector): Open Street Map streams based on NHD (OSM)
- Water bodies (vector): OSM water bodies
- Sawmills (vector): location of the sawmill
- Biomass facilities (vector): location of biomass facilities (USFS)
- SNV RRK study area extent (vector): SNV RRK study area extent

Data Source: Rocky Mountain Research Station

File Name: skidder_bio_cost_proj_clip.tif; skidder_saw_cost_proj_clip2.tif

Reference Tables

Table 1. Road segment travel speed by OSM highway class types.

Query	Speed (MPH)
Residential	25
Unclassified	15
Tertiary	35
Secondary	45
Primary	55
Trunk	55
Motorway	65

Table 2. Criteria used to spatially define harvesting systems and treatment costs. Machine rate of travel, and capacity estimates derived from meetings with Lisa Ball, Jacob Baker (STF), Michael Jow (STF), Brian McCrory, and John Hogland.

Component	System	Rate	Rate of Travel	Payload	Where it can occur
	Rubber Tire Skidder	$165/hr	1.5 MPH	1.25 CCF	Slopes <= 35% and Next to Roads (distance < 460m from a road)
Offroad	Skyline	$400/hr	2.0 MPH	1.04 CCF	Slopes > 35% and within 305m of a road
	Helicopter	$8,000/hr	2.4 MPH	1.67 CCF	Areas not covered by the other two and distance < 915m from landing area
Felling	Feller Buncher	$15/CCF	NA	NA	Slopes <= 35%
	Hand Felling	$27/CCF	NA	NA	Slopes > 35%

Processing	Delimbing, cutting to length, chipping and loading	$56/CCF	NA	NA	NA
On road	Log Truck	$98/hr	Table 1	12.5 CCF	NA
Additional Treatments	Hand Treatment	$2470/ac	NA	NA	Forested Areas
	Prescribed Fire	$2470/ac	NA	NA	Forested Areas

Biomass Residues (40% Thin From Below Treatment)

Tier: 3

Data Vintage: 08/2018

Metric Definition and Relevance: This raster layer represents forest residues for the state of California in 2018. It was developed by the Schatz Energy Research Center as part of the C-BREC (California Biomass Residue Emissions Characterization) model. The raster is based on the LEMMA (Landscape Ecology, Modeling, Mapping, and Analysis) group's forest state data for 2012, which was grown forward to represent residues in 2018 by NRSIG (Natural Resource Spatial Informatics Group) at University of Washington using FVS (Forest Vegetation Simulator).

Data Resolution: 30m Raster

Data Units: Imperial short tons per acre

Creation Method: Pixel values are estimates of the total biomass residue generated by a 40% Thin From Below treatment, reported in imperial short tons per acre. The value for a given pixel is the sum of biomass estimates across all residue size classes (foliage, branches, logs 4-6" in diameter, logs 6-9" in diameter, and logs greater than 9" in diameter).

For more information on the C-BREC model, you can visit the following links:

- C-BREC tool webpage: https://schatzcenter.org/cbrec/
- C-BREC model background and use: https://iopscience.iop.org/article/10.1088/1748-9326/acbd93#erlacbd93s3

Data Source: Schatz Energy Research Center

File Name: BiomassResidues_201808.tif

Fire Adapted Communities

Wildfires are a keystone disturbance process in western US forests. However, the capacity for humans to co-exist in the wildland urban interface (WUI) requires different restoration strategies aimed at the protection of life and property. This pillar evaluates the degree to which communities are living safely with fire and are accepting of management and natural ecological dynamics. It also evaluates the capacity for communities to manage desired, beneficial fire and suppress unwanted fire. A national WUI data layer is provided as part of the project (see Carlson et al. 2022 in the operational data layers). The Forest Service identifies the WUI as the defense zone, ¼ mile of development (infrastructure), with an additional 1 ¼ miles beyond the defense zone defining the threat zone. CALFIRE is updating its delineation of WUI and should be available soon. Each Forest can replace that WUI delineation with their own tailored data layer if one exists. The data source available across the Sierra Nevada and the State is the iCLUS urban development data layer.

DESIRED OUTCOME: Communities have adapted to live safely in forested landscapes and understand the significance of fire to maintaining healthy forests. They have sufficient capacity to manage desired fire and suppress unwanted fire.

Hazard

The fire hazard element characterizes the risk of high and moderate severity fire and threat to infrastructure. This is typically but not exclusively applied to the Wildland Urban Interface (WUI) defense and threat zones.

Structure Exposure Score

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022.

Metric Definition and Relevance: This metric, Structure Exposure Score (SES), was developed by Pyrologix LLC.

Structure Exposure Score is an integrated rating of wildfire hazard that includes the likelihood of a wildfire reaching a given location along with the potential intensity and ember load when that occurs. SES varies considerably across the landscape.

Pyrologix uses a standard geometric-interval classification to define the ten classes of SES, where each class break is 1.5 times larger than the previous break. So, homes located within Class X are 1.5 times more exposed than those in Class IX, and so on.

1. (SES I): 0
2. (SES II): 0.01 to 50
3. (SES III): 50 to 75
4. (SES IV): 75 to 113
5. (SES V): 113 to 169
6. (SES VI): 169 to 253
7. (SES VII): 253 to 380
8. (SES VIII): 380 to 570
9. (SES IX): 570 to 854
10. (SES X): 854+

Data Resolution: 30m raster

Data Units: Relative index, 10 classes

Creation Method: Structure Exposure Score (SES) is a proprietary index representing the level of wildfire exposure for a structure (e.g., a home) if one were to exist on a given pixel. It is an integrated measure that includes three components: the likelihood of a wildfire of any intensity occurring in a given year (annual burn probability), potential wildfire intensity for a given pixel, and ember load to that pixel from surrounding vegetation.

SES data was produced by Pyrologix LLC, a wildfire threat assessment research firm, as part of a spatial wildfire hazard assessment across all land ownerships for the state of California. The ongoing work generally follows the framework outlined in Scott and Thompson (2013), with custom methods and significant improvements developed by Pyrologix. The project generally consists of three components: fuelscape calibration and updates, wildfire hazard assessment, and risk assessment. It utilizes a combination of wildfire models and custom tools, including the FSim large wildfire simulator (Finney et al., 2011), and WildEST, a custom modeling tool developed by Pyrologix (Scott, 2020). To date, this work has resulted in a wide variety of spatial data layers related to wildfire hazard and risk, including Structure Exposure Score (SES), representing conditions prior to the 2020, 2021 and 2022 fire seasons. Work to date has been funded by the USDA Forest Service Region 5, the California Energy Commission, and the USDI Bureau of Land Management with data contributions from CAL FIRE.

For this project, the FSim large-fire simulator is used to quantify annual wildfire likelihood across the analysis area. FSim is a comprehensive fire occurrence, growth, behavior, and suppression simulation system that uses locally relevant fuel, weather, topography, and historical fire occurrence information to make a spatially resolved estimate of the contemporary likelihood and intensity of wildfire across the landscape.

WildEST (Wildfire Exposure Simulation Tool) is used to quantify wildfire intensity and ember loads across the analysis area. WildEST is a deterministic wildfire modeling tool developed by Pyrologix that integrates spatially continuous weather input variables, weighted based on how they will likely be realized on the landscape. This makes the deterministic intensity values developed with WildEST more robust for use in effects analysis than the stochastic intensity values developed with FSim. This is especially true in low wildfire occurrence areas where predicted intensity values from FSim are reliant on a very small sample size of potential weather variables. It also allows for more appropriate weighting of high-spread conditions into fire behavior calculations. WildEST also produces indices of conditional and expected ember production from vegetated areas (pixels) and load to other pixels in the analysis area. Please reference the Pyrologix 2021 project report (Volger et al., 2021) for more information on WildEST analysis.

FSim was run for the CAL 2022 fuelscape at 120m resolution. WildEST was run for the CAL 2022 fuelscape at 30-m resolution. Both models utilized gridded hourly historical California weather data provided by CALFIRE. Results for annual burn probability (FSim), fire intensity (WildEST) and ember load (WildEST) were used to create Structure Exposure Score.

Data Source:

- Pyrologix, LLC

File Name: StructureExposureScore_202308.tif

Damage Potential

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022.

Metric Definition and Relevance: This metric, Damage Potential (DP), was developed by Pyrologix LLC. The composite Damage Potential (DP) dataset represents a relative measure of wildfire's potential to damage a home or other structure if one were present at a given pixel, and if a wildfire were to occur (conditional exposure). It is a function of ember load to a given pixel, and fire intensity at that pixel, and considers the generalized consequences to a home from fires of a given intensity (flame length). This index does not incorporate a measure of annual wildfire likelihood.

Data Resolution: 30m raster

Data Units: Relative index, low to high

Creation Method: DP values were binned based on the following ranges into 6 classes and assigned class names.

0. (None): Values = 0
1. (Very Low): Values 0.01 to 20
2. (Low): Values 20 to 35
3. (Moderate): Values 35 to 50
4. (High): Values 50 to 80
5. (Very High): Values 80+

Damage Potential (DP) data was produced by Pyrologix LLC, a wildfire threat assessment research firm, as part of a spatial wildfire hazard assessment across all land ownerships for the state of California. The ongoing work generally follows the framework outlined in Scott and Thompson (2013), with custom methods and significant improvements developed by Pyrologix. The project generally consists of three components: fuelscape calibration and updates, wildfire hazard assessment, and risk assessment. It utilizes a combination of wildfire models and custom tools, including WildEST (Wildfire Exposure Simulation Tool), a custom modeling tool developed by Pyrologix (Scott, 2020). To date, this work has resulted in a wide variety of spatial data layers related to wildfire hazard and risk, including Damage Potential (DP), representing conditions prior to the 2020, 2021 and 2022 fire seasons. Work to date has been funded by the USDA Forest Service Region 5, the California Energy Commission, and the USDI Bureau of Land Management with data contributions from CAL FIRE. Please reference the Pyrologix 2021 project report (Volger et al., 2021) for more information about the project or WildEST analysis.

Damage Potential (DP) is a proprietary index developed by Pyrologix LLC representing wildfire's potential to damage a home or other structure if a wildfire were to occur (conditional exposure). It is a function of ember load to a given pixel and fire intensity at that pixel, and it considers the generalized consequences to a home from fires of a given intensity (flame length). DP is calculated based on two other datasets developed by Pyrologix: conditional risk to potential structures (cRPS) and conditional ember load index (cELI).

cRPS represents the potential consequences of fire to a home at a given location if a fire occurs there and if a home were located there. It is a measure that integrates wildfire intensity with generalized consequences to a home on every pixel. Wildfire intensity (flame length) is calculated using Pyrologix' WildEST tool. WildEST is a scripted geospatial process used to perform multiple deterministic simulations under a range of weather types (wind speed, wind direction, fuel moisture content). Rather than weighting results solely according to the temporal relative frequencies of the weather scenarios, the WildEST process integrates results by weighting them according to their weather type probabilities (WTP), which appropriately weights high-spread conditions into the calculations. For fire-effects calculations, WildEST generates flame-length probability rasters that incorporate non-heading spread directions, for which fire intensity is considerably lower than at the head of the fire.

The response function characterizing potential consequences to an exposed structure is applied to fire effects flame lengths from WildEST for all burnable fuel types on the landscape regardless of whether an actual structure is present or not. The response function does not consider building materials of structures and is meant as a measure of the effect of fire intensity on structure exposure. The response function is provided below:

- Flame length probability of 0-2 ft: -25
- Flame length probability of 2-4 ft: -40
- Flame length probability of 4-6 ft: -55
- Flame length probability of 6-8 ft: -70
- Flame length probability of 8-12 ft: -85
- Flame length probability of >12 ft: -100

These results were calculated using 30m fire-effects flame-length probabilities from the WildEST wildfire behavior results and then further smoothed.

cELI is also calculated in WildEST, and represents the relative ember load per pixel, given that a fire occurs, based on surface and canopy fuel characteristics, climate, and topography within the pixel. Units are the relative number of embers. cELI is based on heading-only fire behavior.

Damage Potential is then calculated as the arithmetic mean of cELI and cRPS for each pixel across the landscape.

$$DP = cRPS + cELI/2$$

Although flame length and its potential impact to structures is a function of the fire environment at the subject location only, ember load is a function of ember production and transport in the area surrounding the subject location. A location with light fuel (and therefore low flame length) could still have significant Damage Potential if surrounded by a fire environment that produces copious embers.

Data Source:

- Pyrologix, LLC

File Name: DamagePotential_202308.tif

Ember Load Index

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022.

Metric Definition and Relevance: This ember load dataset represents the ember load index (ELI) per pixel, for a given pixel, based on surface and canopy fuel characteristics, climate, and topography within the pixel. The Ember Load Index (ELI) incorporates burn probability (BP). BP is incorporated into calculations of the ember production before the distribution of embers across the landscape to determine ember load. Given that ELI incorporates burn probability, this index can be used to identify where on the landscape hardening buildings may be needed to resist ignition and the priority for doing so according to the likelihood of the area being visited by fire.

Data Resolution: 30m Raster

Data Units: Relative number of embers.

Creation Method: ELI is not simply the multiplication of ember load and burn probability (BP). Rather, BP is incorporated into calculations of the ember production prior to the distribution of embers across the landscape to determine ember load. ELI is based on heading-only fire behavior.

Data Source: Pyrologix, LLC

File Name: EmberLoadIndex_202308.tif

Ignition Cause

Tier: 1

Data Vintage: 1992 - 2020

Metric Definition and Relevance: The original point layer (WildfireOccurrence_CA_1992_2020.shp) contains a spatial database of wildfires that occurred in the United States from 1992 to 2020. It is the fifth update of a publication originally generated to support the national Fire Program Analysis (FPA) system. The wildfire records were acquired from the reporting systems of federal, state, and local fire organizations. The following core data elements were required for records to be included in this data publication: discovery date, final fire size, and a point location at least as precise as a Public Land Survey System (PLSS) section (1-square mile grid). The data were transformed to conform, when possible, to the data standards of the National Wildfire Coordinating Group (NWCG), including an updated wildfire-cause standard (approved August 2020). Basic error-checking was performed and redundant records were identified and removed, to the degree possible. The resulting product, referred to as the Fire Program Analysis fire-occurrence database (FPA FOD), includes 2.3 million geo-referenced wildfire records, representing a total of 180 million acres burned during the 29-year period. Identifiers necessary to link the point-based, final-fire-reporting information to published large-fire-perimeter and operational-situation-reporting datasets are included. Short, Karen C. 2022. Spatial wildfire occurrence data for the United States, 1992-2020 [FPA_FOD_20221014]. 6th Edition. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2013-0009.6

Data Resolution: Vector(points) (1 layer) and 30m Raster (3 layers)

Data Units: Categorical

Creation Method: Rocky Mountain Research Station (U.S. Forest Service) scientist, Karen Short, is the principal creator of this data set. Points were converted to 30m raster cells using the “most frequent” function on the NWCG_CAUSE_CLASSIFICATION attribute (Broad classification of the reason the fire occurred) creating three rasters:

- Human caused ignition
- Lightning (natural) caused ignition
- All causes of ignition - Human or Natural and Missing data/not specified/undetermined

“MostFrqCau” indicates the most frequent cause of the fire in that location.. “FireCount” indicates the number of fires that occurred between 1992 and 2020, regardless of cause. It is noted that locations with hundreds of counts may be a result of the method of how ignitions are reported/recorded. Both the accuracy and precision of the location estimates are generally much lower than that implied by the stored coordinate information – which, for example, may have been calculated from a PLSS section centroid. Efforts were made to purge redundant records to the best of the authors’ ability. Despite this, some locations may have multiple records that may reflect redundant records or multiple reports of fires due to the imprecision of the location record, the reporting process of an individual authority, or the possible reality of multiple initiations at a given location.

Data Source: Rocky Mountain Research Station, U.S. Forest Service

File Name: WldfireAllCausesCount_1992_2020.tif; WldFireOccCause_Human_1992_2020.tif; WldFireOccCause_Natural_1992_2020.tif; WildfireOccurrence_CA_1992_2020.shp

---

Fire Ignition Probability

Tier: 3

Data Vintage: 1992 to 2015

Metric Definition and Relevance: These rasters depict the predicted human- and lightning-caused ignition probability for the state of California. Ignition is regulated by complex interactions among climate, fuel, topography, and humans. Considerable studies have advanced our knowledge on patterns and drivers of total areas burned and fire frequency, but much is less known about wildfire ignition. To better design effective fire prevention and management strategies, it is critical to understand contemporary ignition patterns and predict the probability of wildfire ignitions from different sources. UC Davis researchers modeled and analyzed human- and lightning-caused ignition probability across the whole state and sub-ecoregions of California, USA.

Findings reinforce the importance of varying humans vs biophysical controls in different fire regimes, highlighting the need for locally optimized land management to reduce ignition probability. Based on the most complete ignition database available, researchers developed maximum entropy models to predict the spatial distribution of long-term human- and lightning-caused ignition probability at 1 km and investigated how a set of biophysical and anthropogenic variables controlled their spatial variation in California and across its sub-ecoregions. Results showed that the integrated models with both biophysical and anthropogenic drivers predicted well the spatial patterns of both human- and lightning-caused ignitions in statewide and sub-ecoregions of California. Model diagnostics of the relative contribution and marginalized response curves showed that precipitation, slope, human settlement, and road network were the most important variables for shaping human-caused ignition probability, while snow water equivalent, lightning density, and fuel amount were the most important variables controlling the spatial patterns of lightning-caused ignition probability. The relative importance of biophysical and anthropogenic predictors differed across various sub-ecoregions of California.

Data Resolution: 1km Raster

Data Units: Probability, 0-1

Creation Method: Maximum entropy models were developed to estimate wildfire ignition probability and understand the complex impacts of anthropogenic and biophysical drivers, based on a historical ignition database.

UC Davis researchers developed maximum entropy models to estimate wildfire ignition probability and understand the complex impacts of anthropogenic and biophysical drivers, based on a historical ignition database. Researchers used the US Forest Service Fire Program Analysis-Fire Occurrence Database (FPA-FOD), compiled from reporting systems of US federal, state, and local fire agencies (Short 2017). This homogenized and comprehensive dataset includes wildfire ignition records on both public and private lands from 1992 to 2015, and accounted for many small fires that are not included in many other fire datasets.

Researchers used spatial layers of population density, transportation road network, and nighttime lights, to quantify human settlement and accessibility. Researchers assembled statewide geospatial layers to evaluate the biophysical controls from topography, climate, and fuels on spatial variation of wildland ignitions (table 1). The 2010 global 250 m terrain elevation data (GMTED2010) was used to characterize slope and aspect at 1 km spatial resolution. Weather information came from the gridded Daily Surface Weather and Climatological Summaries meteorological data at 1 km (Daymet) (Thornton et al 2020), including precipitation (Prcp), minimum and maximum temperature (Tmin and Tmax), incident shortwave radiation (Srad), water vapor pressure (VP), and snow water equivalent (SWE), or the amount of water that would be released from melting snowpack. We derived long-term annual means during 1992–2015 for these meteorological variables at 1 km.

Researchers modeled the spatial pattern of ignition probability using the maximum entropy statistical method (MaxEnt v3.3.3k) (Phillips et al 2004, 2006, 2021). MaxEnt is a machine-learning technique originally designed to model species distribution from presence-only data using multidimensional environmental inputs (Phillips et al 2004, 2006). It estimates a target probability distribution by iteratively searching for the probability distribution with maximum entropy (i.e. the one that is most uniform), subject to the environmental variables at each observation (i.e. presence-only point).

The models captured well the spatial patterns of human and lightning started wildfire ignitions in California. The human-caused ignitions dominated the areas closer to populated regions and along the traffic corridors. Model diagnosis showed that precipitation, slope, human settlement, and road network shaped the statewide spatial distribution of human-started ignitions. In contrast, the lightning-caused ignitions were distributed more remotely in Sierra Nevada and North Interior, with snow water equivalent, lightning strike density, and fuel amount as primary drivers. Separate region-specific model results further revealed the difference in the relative importance of the key drivers among different sub-ecoregions.

Data Source: Bin Chen and Yufang Jin, University of California Davis, bch@ucdavis.edu

Spatial patterns and drivers for wildfire ignitions in California - IOPscience

Short K C 2017 Spatial wildfire occurrence data for the United States, 1992-2015 [FPA_FOD_20170508]

File Name: PredictedHumanIgnitionProb_1km_1992_2015.tif; PredictedLightningIgnitionProb_1km_1992_2015.tif

---

Source of Ember Load to Buildings

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022.

Metric Definition and Relevance: The ember transport model used in WildEST tracks the travel of embers from each source pixel to downwind receiving pixels. The relative number of embers landing on a given receiving pixel is summed across all potential source pixels. If the receiving pixel has a nonzero WRC Building Cover value (meaning the pixel is within 75 m of a qualifying building), then we separately sum the relative number of embers from the source pixel. The final SELB raster represents the expected annual relative ember production that lands on building cover across all weather types.

Data Resolution: 30m Raster

Data Units: Relative index

Creation Method: The WildEST modeling contains a module for producing indices of conditional and expected ember production and load. The Conditional Ember Production Index (cEPI) is an index of the relative number of embers lofted at a given landscape pixel given the fire environment there, given that a fire occurs. Ember Production Index (EPI) is the expected value of cEPI; it is the expected annual relative number of embers lofted from a given landscape pixel.

The Conditional Ember Load Index (cELI) is a relative index of the relative number of embers that land at a given landscape location, including nonburnable pixels. Finally, Ember Load Index combines the conditional ELI and the likelihood of that ember load occurring. All ember characteristics are based on headfire behavior. These

The ember load indices represent relative ember load at a pixel. Similar to ember production, ember load is also based on surface and canopy fuel characteristics, climate, and topography at the pixel. Ember load incorporates downwind ember travel.

The Ember Load Index (ELI) incorporates burn probability; however, ELI is not simply the multiplication of condition ember load (cELI) and burn probability (BP). Rather, BP is incorporated into calculations of the ember production before the distribution of embers across the landscape to determine ember load. Given that ELI incorporates burn probability, this index can be used to identify where on the landscape hardening buildings may be needed to resist ignition and the priority for doing so according to the likelihood of the area being visited by fire.

Data Source: Pyrologix, LLC

File Name: SourceEmberLoadToBuildings_202308.tif

Wildfire Hazard Potential

Tier: 1

Data Vintage: 08/2022. Includes disturbances through the end of 2021.

Metric Definition and Relevance: Wildfire Hazard Potential (WHP) is an index that quantifies the relative potential for wildfire that may be difficult to control. WHP can be used as a measure to help prioritize where fuel treatments may be needed.

Data Resolution: 30m Raster

Data Units: Relative index

Creation Method: Pyrologix calculated WHP following the methods established by Dillon et al. (2015) and Dillon (2018). The original methods utilize lower-resolution FSim inputs, while our approach uses higher-resolution inputs including 30-m CAL vegetation inputs (derived from LANDFIRE 2016), 30-m CAL fuel model outputs, 30-m CAL burn probability results, and 30-m CAL fire-effects flame-length probabilities from the WildEST wildfire behavior results.

Data Source: Pyrologix, LLC

File Name: WildfireHazardPotential_202208.tif

Fire Dynamics

Fire dynamics reflect fire as an ecological process and the function that it performs. It can be broken into two key elements: functional fire and fire severity. Although fire dynamics pertain to the entire landscape, the ecological role of fire is most relevant to landscapes outside of the wildland urban interface (WUI). Within the WUI, protection of life and property takes priority over the role of fire as a process. As a result, this fire dynamics pillar pertains to areas outside of the WUI while the fire-adapted communities pillar pertains to areas inside the WUI.

DESIRED OUTCOME: Fire burns in an ecologically beneficial and socially acceptable way that perpetuates landscape heterogeneity and rarely threatens human safety or infrastructure.

Functional Fire

Increasing the pace and scale of restoration on the landscape will require using a variety of tools to accomplish restoration targets. The use of prescribed fire and managed wildfires, where appropriate, can contribute to the restoration need. This is particularly true where fires burn at low and moderate severity, which we are referring to as "functional fire". Functional fire is when fire burns in an ecologically beneficial and socially acceptable way, perpetuating landscape heterogeneity and rarely threatening human safety or infrastructure.

Discussion of the Fire Return Interval Departure (FRID) Methods

Definition and Relevance: The fire return interval departure (FRID) analysis quantifies the difference between current and pre-settlement fire frequencies, allowing managers to target areas at high risk of threshold-type responses owing to altered fire regimes and interactions with other factors.

Creation Method: The FRID methodology was developed and described by Van de Water and Safford (2011). The feature class is now produced and maintained by the U.S. Forest Service, Region 5, Information Management – Mapping and Remote Sensing (MARS) Team. Contemporary FRIs were calculated using the fire dates and footprints from California Interagency Fire Perimeters database (maintained by the California Department of Forestry and Fire Protection (CalFire-FRAP). The vegetation type stratification (i.e. to calculate the FRI for individual vegetation types) was based on the MARS Existing Vegetation (EVEG) map for California from the year 2011, with the vegetation typing ("CALVEG") cross-walked (grouped) into 28 pre-settlement fire regime (PFR) types.

For assorted reasons, portions of San Benito and San Luis Obispo Counties never received a full EVEG Baseline Mapping assessment and thus data in the FRID Central California layer has some holes in these areas. In 2009, an EVEG mapping project was started for these areas but never finalized. San Luis Obispo County, the southern part of Santa Clara County, and all of San Benito County were baseline mapped using the Hardwood Dataset as a foundation for regional dominance (vegtype). Additional data sources from the National Land Cover Database, San Luis Obispo County Farm Data, Farmland Mapping & Monitoring Program, Bureau of Reclamation, and National Hydrology Database were then used to overwrite the Hardwood data where it was relevant. Structural attributes for forested conditions came primarily from the Hardwoods Dataset for canopy values while tree size was derived from a classification of Thematic Mapper 30-meter imagery.

Preparation of the Fire Return Interval Departure (FRID) data requires use of up to date statewide vegetation data. For this purpose we have been using EVEG, as described above. This has been adequate for most of California but there are some areas, because of missing data, that required some adjustments.

Although incomplete as an EVEG database, these "best available data"were used by the RRK team to fill holes in FRID for the Central California RRK project. The MARS team completed a crosswalk from Regional Dominance Type

1 (vegtype) to the FRID PFR attribute and calculations for the "gap" areas were run for fire return interval departure. We have used this "patch" to address FRID needs for the near-term. The data for these areas will show vulnerabilities to analysis at larger scales until a time that these areas can be visually edited to match the level of precision seen in the adjoining Los Padres NF.

Other gaps (NoData):

Although areas mapped as grasslands and meadows were included in the GIS layer, FRI and departure statistics were not calculated for these types because reliable information about pre-Euro American settlement fire regimes is lacking. These values (-999) have been converted to NoData in the RRK datasets.

Data Source: USDA Forest Service, Region 5, MARS Team

References: Information on pre-Euromerican settlement FRIs (fire return intervals) was compiled from an exhaustive review of the fire history literature, expert opinion, and vegetation modeling (Van de Water and Safford 2011; Safford and Van de Water 2014). Contemporary FRIs were calculated using the California Interagency Fire Perimeters database (maintained by the California Department of Forestry and Fire Protection (CAL FIRE-FRAP). The vegetation type stratification was based on the US Forest Service existing vegetation map (USDA Forest Service, Mapping and Remote Sensing Team) for California from the year 2011, with the vegetation typing ("CALVEG") grouped into 28 pre-settlement fire regime (PFR) types, as defined by Van de Water and Safford (2011). The 2011 eVeg map is used as the baseline for all subsequent FRID maps to freeze the underlying vegetation template and permit temporal comparisons without introducing vegetation type change as a confounding factor.

Current Fire Return Interval Departure, Since 1908

Tier: 3

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: The fire return interval departure (FRID) analysis quantifies the difference between current and pre-settlement fire frequencies, allowing managers to target areas at high risk of threshold-type responses owing to altered fire regimes and interactions with other factors. This is a measure of the extent to which contemporary fires (i.e. since 1908) are burning at frequencies similar to the frequencies that occurred prior to Euro-American settlement.

Data Resolution: 30m Raster

Data Units: Average Years

Creation Method: Current fire return interval 1908 is calculated by dividing the number of years in the fire record by the number of fires occurring between 1908 and the current year in a given polygon plus one.

CurrentFRI = Number of years/Number of Fires +1

Data Source:

Fire History (2022), CAL FIRE
Existing Vegetation (CALVEG 2011), USDA Forest Service, Region 5, MARS Team

File Name: currentFRI_2022.tif

Current Fire Return Interval Departure, Since 1970

Tier: 2

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: The fire return interval departure (FRID) analysis quantifies the difference between current and pre-settlement fire frequencies, allowing managers to target areas at high risk of threshold-type responses owing to altered fire regimes and interactions with other factors. This is a measure of the extent to which contemporary fires (i.e. since 1970) are burning at frequencies similar to the frequencies that occurred prior to Euro-American settlement, with the mean reference FRI as the basis for comparison. With this metric, mPFRID_1970, the same formulas are used as with meanPFRID but with 1970 as the baseline rather than 1908. Important note: because 1970 is the baseline for this measure, no fires before 1970 are taken into account and all PFRs start at a PFRID of zero beginning in 1970.

Data Resolution: 30m Raster

Data Units: Average Years

Creation Method: Current fire return interval 1970 is calculated by dividing the number of years in the fire record by the number of fires occurring between 1970 and the current year in a given area plus one.

$$CurrentFRI\_1970 = Number\ of\ years/Number\ of\ Fires\ +1$$

Data Source:

Fire History (2022), CAL FIRE
Existing Vegetation (CALVEG 2011), USDA Forest Service, Region 5, MARS Team

File Name: currentFRI_1970_2022.tif

Mean Percent FRI Departure, Since 1908

Tier: 3

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: This metric, mean percent FRID, is a measure of the extent to which contemporary fires (i.e., since 1908) are burning at frequencies similar to the frequencies that occurred prior to Euro-American settlement, with the mean reference FRI as the basis for comparison. Mean PFRID is a metric of fire return interval departure (FRID), and measures the departure of current FRI from reference mean FRI in percent.

Data Resolution: 30m raster

Data Units: Percent

Creation Method: The current FRI is calculated by dividing the number of years in the fire record (e.g., 2019-1908=112 years inclusive) by the number of fires occurring between 1908 and the current year in a given polygon plus one (CurrentFRI = Number of years/Number of fires +1). The mean reference FRI is an approximation of how often, on average, a given PFR likely burned in the three or four centuries prior to significant Euro-American settlement. This measure does not return to zero when a fire occurs, unlike FRID values used in some other analyses (e.g., NPS FRID Index). Instead, the following formulas are used to calculate Mean PFRID:

When current FRI is longer than reference FRI (the common condition in most coniferous PFRs) the formula is:

$$[1-(MeanRefFRI/CurrentFRI)]*100$$

When current FRI is shorter than reference FRI (common in some shrub dominated PFRs, and areas in the Wildland Urban Interface) the formula is:

$$-\{[1-(CurrentFRI/MeanRefFRI)]\}*100$$

For areas dominated by PFRs with a mean reference FRI greater than 112 years, and that have not burned in the period of historical record considered in this analysis (i.e., since 1908), the FRID is assumed to equal zero.

Data Source:

- Fire History (2022), CAL FIRE
- Existing Vegetation (CALVEG 2011), Region 5, MARS Team

File Name: meanPFRID_2022.tif

Mean Percent FRI Departure, Since 1970

Tier: 2

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: Percent FRID (PFRID) quantifies the extent in percentage to which recent fires (i.e., since 1970) are burning at frequencies similar to those that occurred prior to Euro-American settlement, with the mean reference FRI as the basis for comparison. Mean PFRID measures the departure of current FRI from reference mean FRI in percent

Data Resolution: 30m Raster

Data Units: Percent

Creation Method: The current FRI is calculated by dividing the number of years in the fire record (e.g., 2019-1970=49 years inclusive) by the number of fires occurring between 1970 and the current year in a given polygon plus one (CurrentFRI = Number of years/Number of fires +1). The mean reference FRI is an approximation of how often, on average, a given PFR likely burned in the three or four centuries prior to significant Euro-American settlement. This measure does not return to zero when a fire occurs, unlike FRID values used in some other analyses (e.g., NPS FRID Index).

Data Source:

- Fire History (2022), CAL FIRE
- Existing Vegetation (CALVEG 2011), Region 5, MARS Team

File Name: meanPFRID_1970_2022.tif

Mean FRID Condition Class For Departure

Tier: 2

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: This metric, uses the mean percent FRID to a measure of the extent to which contemporary fires (i.e., since 1908) are burning at frequencies similar to the frequencies that occurred prior to Euro-American settlement, with the mean reference FRI binned into another basis for comparison. Mean PFRID is a metric of fire return interval departure (FRID), and measures the departure of current FRI from reference mean FRI in percent.

Data Resolution: 30m raster

Data Units: Integer, -3 to 3

Creation Method: This is a condition class categorization of the data in the Mean PFRID field. MeanCC_FRI categorizes the percent differences calculated in Mean PFRID using the following scale:

- 1: 0 to 33.3% departure
- 2: 33 to 66.7% departure
- 3: >66.7% departure

Negative condition classes (i.e., where fires are burning more often than under pre-Anglo-American settlement conditions) are categorized on the negative of the same scale:

- -1: 0 to -33.3%
- -2: -33 to -66.7%
- -3: <-66.7%

CC1 and CC-1 are mapped in the same class because they are both within 33% of the mean pre-settlement value.

Data Source:

- Fire History (2022), CAL FIRE
- Existing Vegetation (CALVEG 2011), Region 5, MARS Team

File Name: meanCC_FRI_2022.tif

Time Since Last Fire

Tier: 2

Data Vintage: 2022. Includes disturbances through the end of 2022.

Metric Definition and Relevance: Time Since Last Fire (TSLF), from the Fire Return Interval Departure (FRID) map, provides information (in years) to indicate the length of time since an area last burned.

Data Resolution: 30m raster

Data Units: Years

Creation Method: Time Since Last Fire (TSLF), from the Fire Return Interval Departure (FRID) map, provides information (in years) to indicate the length of time since an area last burned. Specifically, the number of years elapsed between the most recent fire recorded in the fire perimeters database and the version year of the FRID map being used. To illustrate, if the version year of the FRID map is 2019, and the area in question last burned in 1995, TSLF will be 24 (2019 minus 1995).

Data Source:

- Fire History (2022), CAL FIRE
- Existing Vegetation (CALVEG 2011), Region 5, MARS Team

File Name: TSLF_2022.tif

Severity

Uncharacteristic proportions of high severity fire over the area burned, particularly in the last decade, has been a common theme in the megafires that have occurred throughout the Sierra recently. The following metrics characterize, map, and quantify some of the factors that contribute.

Total Dead/Down Fuels

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Stephens et al. (2022) note that total dead/down values over 20 (short) tons/ac (40 Mg/ha) resulted in high severity in 56% of the pixels. Higuera and Abatzoglou (2020) note that fuel and fuel aridity, **where fuel is "non-limiting"**, are a primary control on area burned at interannual to millennial timescales. Thus, it is more important than ever to define fuel limitation and map where it is on the landscape as a fundamental metric for where, even under hotter climates, low to moderate severity fire is still a strong likelihood.

Data Resolution: 30m raster

Data Units: Short tons/acre

Creation Method: The F3 model generated several different raster surfaces of fuel loading estimates of the coarse woody debris by non-overlapping predefined size classes; including 1, 10, 100, 1000-hour fuels (FLOAD_1-5). The model also produced estimates for coarse woody debris of heavy fuels by non-overlapping predefined size classes which are greater than the 1000-hour fuel size (>=12"; FLOAD_6-9) and for litter and duff.

2019 to 2021 Update: No adjustments were made for 2021 due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), total dead/down fuel values are not represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that total dead/down fuels did not change significantly over the course of two years.

This layer for the Total Dead/Down Fuels metric is derived from F3 layers (2021) using the following formula:

sum(FLOAD_1-9, LITTER, DUFF)

Data Source: F3 data outputs, Region 5, MARS Team

File Name: TotalFuelLoad_2021_30m.tif

Standing Dead and Ladder Fuels

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: This is the material that may burn at the extreme end of the spectrum and contribute to mass fire behavior (Stephens et al., 2022), especially during crown spread type events. Live "ladder" fuels for trees less than 10" in diameter are also included in this calculation.

Data Resolution: 30m raster

Data Units: Short tons/acre

Creation Method: The F3 model generated raster surfaces to estimate the small size live trees (those <10" DBH) branchwood and foliage plus unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x) as ladder fuels. The model also generated the standing dead estimates for all size classes (including stems, branches, and foliage still present) from the FVS Fire and Fuels extension carbon report (Standing_D).

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss, following the formula:

$$2021\ BMCWN\_x = 2019\ BMCWN\_x - (2019\ BMCWN\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among predefined size classes may result in over- or under-estimates of actual small size trees, depending on location.

Adjustments for the standing dead trees raster (Standing_D) took the difference between 2019 and 2021 live volume (as estimated using eDaRT MMI) converted to short tons/acre using a conversion factor of 32.1 cubic feet/ton and the result was summed with 2019 standing dead. This adjusted value was then added to the non-overlapping, predefined size classes for the small size live trees (<10" DBH) branchwood and foliage plus unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x), which had been adjusted for 2021 using MMI percent adjustments.

This layer for the Standing Dead and Ladder Fuels metric is derived from F3 layers (2021) using the following formula:

$$sum(Standing\_D, BMCWN\_0, BMCWN\_2, BMCWN\_7)$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: StdDeadLadFuels_2021_30m.tif

Total Fuel Exposed to Fire

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: This is the sum of standing dead, ladders, and the dead and down, documented above. This metric quantifies the total amount of biomass available to contribute to the extreme fire intensity and spread rates that lead to high severity fire (Stephens et al., 2022).

This metric is also applicable to the Air Quality pillar, in that total fuel load is a value often required in smoke management plans to get Rx fire projects approved.

Data Resolution: 30m raster

Data Units: Short tons/acre

Creation Method: The F3 model generated several raster surfaces; to estimate the small size live trees (those <10" dbh) branchwood and foliage plus the unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x), to estimate fuel loading of coarse woody debris in non-overlapping predefined size classes (FLOAD_x), to estimate both litter and duff, and to estimate the standing dead for all size classes (including stems, branches, and foliage still present) from the FVS Fire and Fuels extension carbon report (Standing_D).

2019 to 2021 Update: The 2021 values (described below) from the Standing Dead and Ladder Fuels and from the Total Dead/Down Fuels, were summed to derive this metric.

Values for 2021 Standing Dead and Ladder Fuels (Standing_D, BMCWN_x) were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass loss, following the formula:

$$2021\ BMCWN\_x = 2019\ BMCWN\_x - (2019\ BMCWN\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and biomass should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among predefined size classes, may result in over- or under-estimates of actual ladder fuels, depending on location.

Adjustments for the standing dead trees raster (Standing_D) took the difference between 2019 and 2021 live volume (as estimated using eDaRT MMI) converted to short tons/acre using a conversion factor of 32.1 cubic feet/ton and the result was summed with 2019 standing dead. This adjusted value was then added to the non-overlapping, predefined size classes for the small size live trees (<10" DBH) branchwood and foliage plus unmerchantable portions of stemwood above 4-inch diameter (BMCWN_x), which had been adjusted for 2021 using MMI percent adjustments.

Values for 2021 Total Dead/Down Fuels (FLOAD_x, LITTER, DUFF) were not adjusted due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of the metric. For areas undisturbed 2019-2021, it is a reasonable assumption that total dead/down fuels did not change significantly over the course of two years. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), total dead/down fuel values are not represented for 2021 (i.e., NULL).

This layer for the Total Fuel Exposed to Fire metric is derived from F3 layers (2021) using the following formula:

$$[sum(Standing\_D, BMCWN\_0, BMCWN\_2, BMCWN\_7, FLOAD\_1\text{-}9, LITTER, DUFF)]$$

In cases where any individual input to the formula is NULL, the resulting sum cannot be computed and is therefore also NULL.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: TotFuelExpFire_2021_30m.tif

Annual Burn Probability

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022

Metric Definition and Relevance: Annual Burn Probability represents the likelihood of a wildfire of any intensity occurring at a given location (pixel) in a single fire season. In a complete assessment of wildfire hazard, wildfire occurrence and spread are simulated in order to characterize how temporal variability in weather and spatial variability in fuel, topography, and ignition density influence wildfire likelihood across a landscape. In such cases, the hazard assessment includes modeling of burn probability, which quantifies the likelihood that a wildfire will burn a given point (a single grid cell or pixel) during a specified period of time. Burn probability for fire management planning applications in this case is reported on an annual basis - the probability of burning during a single fire season.

Data Resolution: 30m raster

Data Units: Probability, 0 to 1

Creation Method: Annual Burn Probability was produced by Pyrologix LLC, a wildfire threat assessment research firm, as part of a spatial wildfire hazard assessment across all land ownerships for the state of California. The ongoing work generally follows the framework outlined in Scott and Thompson (2013), with custom methods and significant improvements developed by Pyrologix. The project generally consists of three components: fuelscape calibration and updates, wildfire hazard assessment, and risk assessment. It utilizes a combination of wildfire models and custom tools, including the FSim large wildfire simulator (Finney et al., 2011). To date, this work has resulted in a wide variety of spatial data layers related to wildfire hazard and risk, including Annual Burn Probability, representing conditions prior to the 2020, 2021 and 2022 fire seasons. Work to date been funded by the USDA Forest Service Region 5, the California Energy Commission, and the USDI Bureau of Land Management with data contributions from CAL FIRE.

For this project, the USFS modeling system called FSim is used to quantify annual wildfire likelihood across California. The model is parameterized using spatial datasets of historical weather, fire occurrence, fuels, weather, and topography in order to simulate thousands of fire-years on a landscape. Annual Burn Probability is calculated from these simulations using a Monte Carlo approach to make a spatially resolved estimate of the contemporary annual likelihood of wildfire across the landscape. For more information on FSim or the wildfire hazard modeling being performed by Pyrologix, please see Volger et al., 2021.

Data Source: Pyrologix, LLC

File Name: AnnualBurnProbability_202308.tif

Probability of Fire Severity (Low, Moderate, High)

Tier: 1

Data Vintage: 08/2023. Includes disturbances through the end of 2022

Metric Definition and Relevance: These metrics represent the probability of low, moderate, or high severity fire, respectively, as constructed by Pyrologix LLC. Operational-control probability rasters indicate the probability that the headfire flame length in each pixel will exceed a defined threshold for certain types of operational controls, manual and mechanical.

Low severity fire represents fire with flame lengths of less than 4 feet and can be controlled using manual control treatments. Moderate severity fire represents fire with flame lengths between 4 and 8 feet and can be controlled using mechanical control treatments. High severity fire represents fire with flame lengths exceeding 8 feet and are generally considered beyond mechanical control thresholds.

Data Resolution: 30m raster

Data Units: Probability, 0 to 1

Creation Method: Probability of High Fire Severity (>8 ft) was produced by Pyrologix LLC, a wildfire threat assessment research firm, as part of a spatial wildfire hazard assessment across all land ownerships for the state of California. The ongoing work generally follows the framework outlined in Scott and Thompson (2013), with custom methods and significant improvements developed by Pyrologix. The project generally consists of three components: fuelscape calibration and updates, wildfire hazard assessment, and risk assessment. To date, this work has resulted in a wide variety of spatial data layers related to wildfire hazard and risk, including operational control probabilities based on conditions prior to the 2020, 2021 and 2022 fire seasons. Work to date has been funded by the USDA Forest Service Region 5, the California Energy Commission, and the USDI Bureau of Land Management with data contributions from CAL FIRE. Please reference the Pyrologix 2021 project report (Volger et al., 2021) for more information.

Pyrologix uses the Wildfire Exposure Simulation Tool (WildEST), a deterministic wildfire modeling tool that integrates variable weather input variables and weights them based on how they will likely be realized on the landscape. WildEST is more robust than the stochastic intensity values developed with FSim. This is especially true in low wildfire occurrence areas where predicted intensity values from FSim are reliant on a very small sample size of potential weather variables.

The low severity fire raster (<4 ft) is created using the Pyrologix raster, xmanualctrl_4 which is fire that can be controlled using manual control and is calculated as

$$1 - xmanualctrl\_4$$

The moderate severity fire raster (4-8 ft) is created using the Pyrologix raster, xmechctrl_8, which is fire that can be controlled using mechanical control and xmanualctrl_4 (manual control) and is calculated as

$$xmanualctrl\_4 - xmechctrl\_8$$

The high severity fire raster (xmechctrl_8) was developed using WildEST; the raster is directly from the Pyrologix library and represents fires which are expected to exceed mechanical control treatments (> 8 ft).

Data Source: Pyrologix, LLC

File Name: ProbabilityLowFireSev_202308.tif; ProbabilityModerateFireSev_202308.tif; ProbabilityHighFireSev_202308.tif

Forest and Shrubland Resilience

Forest and shrubland resilience is the ability of forest and shrubland vegetation and structure to remain a forest or shrubland in the face of disturbance (e.g., fire, forest management, climate change, etc.). The Forest and Shrubland Resilience Pillar evaluates forest and shrubland vegetation composition and structure to determine its alignment with desired disturbance dynamics and within tolerances of current and future biophysical conditions when considering changes due to climate change. The last 100 years of forest and shrubland management, combined with changing climates, have resulted in forest and shrubland structure and composition which are not resilient to contemporary disturbances. Forest or shrubland structure and composition are one of the few elements of a wildland that management can modify through treatments to improve conditions.

DESIRED OUTCOME: Vegetation composition and structure align with topography, desired disturbance dynamics, and landscape conditions, and are adapted to climate change.

Structure

Forest or shrubland structure is the spatial distribution of vegetation (live and dead) both vertically and horizontally on the landscape. Prior to European settlement, forests in the Sierra Nevada were characterized by heterogeneous spatial patterns replete with individual large trees, gaps, and tree clumps of various sizes – patterns that were shaped by recurrent fire and other disturbances. After a century-plus of fire exclusion, timber harvesting, agricultural development, urbanization, and other land-use practices, the predominant trend across Californian landscapes is that they have become less resilient to natural and human-caused disturbances. In many cases some sort of restoration treatment may be necessary to reverse these trends.

Density – Large Trees

Tier: 2

Data Vintage: 06/2020

Metric Definition and Relevance: Large trees are important to forest managers for multiple reasons: they have a greater likelihood of survival from fire; they are an important source of seed stock; they provide vitally important wildlife habitat; and they contribute to other critical processes like carbon storage and nutrient cycling. Large trees are often the focus of management in order to protect existing ones and to foster recruitment of future ones., “Large trees” have been designated in two categories, 24”-30”and greater than 30” dbh. The data provided are an estimate of density of trees (in each dbh class) within a pixel.

Data Resolution: 30m Raster

Data Units: Percent live trees per pixel

Creation Method: To determine the cutoff for large trees, we developed an allometric equation to predict tree diameter as a function of height. We selected data for plots located in the Sierra Nevada region from the USDA Forest Inventory and Analysis program (FIA) for California (FIA DataMart 2023; California 2022 database; ver. 9.0.1).

We included trees that met the following criteria: alive; crown class code of open-grown, dominant, or co-dominant; diameter at breast height (DBH, breast height = 4.5 ft) at least 1 inch; and height (HT) at least 5 feet. To minimize the impact of outliers, we trimmed the maximum tree height to the 0.995th percentile. These selection criteria yielded 82,444 trees. We used an information theoretic approach to select the best allometric model (Burnham and Anderson 2002). We evaluated three alternative functions: : linear, power, and saturating. The criteria for model selection were based on the Akaike Information Criterion (AIC). For this set of 3 potential models, we calculated the difference in AIC between every model and the model with the lowest AIC (ΔAIC).

The best allometric model was a saturating function where:

DIA = (187.2*HT)/(588.5+HT)

The root mean square error on the DBH prediction was 6.02 in and the pseudoR^2 = 0.71. Predicted diameters from heights are summarized here:.

Predicted DBH (in)	Height (ft)
<=1	<=3
>1-6	>3 - 19
>6-11	>19 - 37
>11-24	>37 - 87
>24-30	>87 - 112
30+	>112

Block statistics were run on California Forest Observatory (CFO) canopy height pixels for the following ranges with a 3x3 window to calculate the sum for input cells within a 30m rectangular neighborhood. This assigned number of pixels per 30m (900m2) cell. Resultant values of 1 through 9 were converted to percent.

- 24in - 30in
- greater than 30in

References

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. New York, Springer-Verlag.

FIA DataMart. 2023. USDA Forest Inventory and Analysis DataMart. https://experience.arcgis.com/experience/3641cea45d614ab88791aef54f3a1849/

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: LargeTreeDensity_24in_30in_202006.tif; LargeTreeDensity_gt30in_202006.tif

---

Natural Conifer Regeneration Probability

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: This metric is intended to be used to identify areas where reforestation may be necessary if stakeholders want to reestablish coniferous forests following fire. Conifers in our region generally lack the capacity to resprout after fire and are thus dependent on seedling recruitment for regeneration. Under pre colonial fire regimes – of frequent, small, and typically lower severity fires – conifer seeds were generally able to travel the relatively short distances from live trees to burnt patches. In contrast, the recent emergence of large stand-replacing fires poses a significant challenge for conifer regeneration because long-distance seed dispersal events – needed to span the long distances between surviving trees and large burnt patches – are relatively rare. As a result, many areas formerly occupied by conifers may be poised for vegetation type conversion if conifers are not deliberately replanted.

Data Resolution: 30m raster

Data Units: Probability, 0 to 1

Creation Method: This metric is the modeled probability of natural conifer regeneration – within 4.4m radii (60 m^2) circular plots, five years after fire – for fires occurring from 2012 to 2021. In areas that burned more than once, the probability of regeneration following the most recent fire is reported.

The predictive model was fit using data from 1,234 4.4m radius (60 m^2) plots, spanning 19 wildfires, each measured five years after wildfire (Stewart et al. 2021). Predictor variables include seed availability, burn severity, postfire precipitation 1 – 5 water years following each fire, slope, and equinox solar insolation. Burn severity was derived from Landsat composite imagery using methods derived from Parks et al (2018). Topographically downscaled postfire precipitation data was used as available (i.e., up to the 2022 water-year) and assumed to be equivalent to historical mean conditions (1981 – 2010) for future or incomplete water-years (Daly et al. 1994). Species-specific seed availability was derived from available forest structure maps (2012-2017; Ohmann et al. 2011), allometric equations, a dispersal kernel, and a basal-area-loss-to-fire function (Stewart et al. 2021).

When available, average species-specific basal area up to 5 years following fire was used to estimate seed availability. When unavailable (i.e., for 2017-2021 fires), a composite of 2016 and 2017 structure maps were adjusted to account for the effects of subsequent fires. I.e., to avoid unreliable regions of the 2017 forest structure map – that were derived from summer composite imagery that spans a period both before, during, and after 2017 fires – the 2016 map (adjusted for 2017 fire effects) was used in these areas. Subsequent years were adjusted for the effects of wildfires that occurred from 2018 to 2021. For additional details see Stewart et al. (2021) or the Postfire Conifer Reforestation Planning Tool (accessed at: https://reforestationtools.org/postfire-conifer-reforestation-planning-tool/). Predictions were made using version 0.125 of the Postfire Conifer Reforestation Planning Tool.

- Postfire regeneration and seed production data, Stewart et al. 2022
- Monthly climate data, Daly et al 1994
- Forest structure maps, Ohmann et al. 2011
- National Elevation Dataset, USGS
- Landsat 4-8, NASA
- Fire History (2021), CAL FIRE
- Postfire mortality data, Miller et al. 2009

Data Source: Department of Plant Sciences, UC Davis

File Name: most_recent_postfire_conifer_regen_prob_2012to2021.tif

---

Basal Area

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Basal area (BA) is a common forest structure measurement that provides a useful index of forest and habitat condition. Basal area is the cross-sectional area of the bole of a tree at diameter breast height (dbh). It is measured at the stand level as the cumulative sum of basal area of all trees and expressed as square feet per acre.

Data Resolution: 30m raster

Data Units: Sq ft/acre

Creation Method: The F3 model generated several raster surfaces as estimates of basal area. This raster surface represents all live trees greater than 1" dbh (BASATOT).

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate basal area loss, using the formula:

$$2021\ Basal\ Area = 2019\ Basal\ Area - (2019\ Basal\ Area * MMI/100)$$

Although the assumption of direct correlation between canopy cover and basal area should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022).

Data Source: F3 data outputs, Region 5, MARS Team

File Name: BASATOT_2021_30m.tif

Density – Trees Per Acre

Tier: 2

Data Vintage: 2022

Metric Definition and Relevance: Trees per acre (TPA) is a common forest structure measurement that provides a useful index of forest and habitat condition. Many other metrics can be derived from having accurate estimates of trees per acre.

Data Resolution: 30m raster

Data Units: Live trees/acre

Creation Method: The F3 model generated several raster surfaces of trees per acre as estimates of tree density on the landscape. This raster surface represents all live trees greater than 1" dbh (TPA). Reference conditions can be generated from contemporary reference sites for mature forest conditions outside of the WUI.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA = 2019\ TPA - (2019\ TPA * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022).

Data Source: F3 data outputs, Region 5, MARS Team

File Name: TPA_2021_30m.tif

Density – Snags

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The number of standing dead trees (snags) on the landscape is important to forest managers; high densities of standing dead trees are known to contribute to extreme fire events while snags of certain sizes provide critical habitat to wildlife. For this metric, the snag density for all species and all decay classes with diameters of 20" dbh and greater have been estimated.

Data Resolution: 30m raster **Data Units:** Standing dead trees/acre

Creation Method: The F3 model generated several raster surfaces of snags per acre for all species and all decay classes in non-overlapping, predefined size classes. For this metric, the three largest, predefined non-overlapping size categories have been included: 20-29.9", 30-39.9", and >=40".

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. Each of the predefined non-overlapping size category trees per acre rasters (TPA_x) were adjusted following the same procedure. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA\_x = 2019\ TPA\_x - (2019\ TPA\_x * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree density loss per individual size class, depending on location.

This loss of live trees per acre (TPA) between 2019 and 2021 was then added to the 2019 estimate for snag density (of the same size category; SNG_x) from F3. The layers for Snag Density were each derived from F3 layers (2021) using the following formula:

$$(2019\ TPA\_x - 2021\ TPA\_x) + 2019\ SNG\_x$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: SNG_25_2021_30m.tif; SNG_35_2021_30m.tif; SNG_40_2021_30m.tif

---

Stand Density Index

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Stand density index (SDI) helps vegetation managers to identify levels of site utilization and competition to determine management scenarios to meet objectives and is often used for forest health-oriented treatments. SDI was also proposed by North et al., (2022) as an operational resilience metric for western fire adapted forests. This metric is a quantitative measure that relates the current stand density to the size class distribution of the stand. Reineke uses quadratic mean diameter, a weighted mean, to estimate the stand size class, whereas the Zeide method (also known as the summation method) uses D_r (Reineke's diameter). For additional details on both calculations, see the Essential FVS Guide.

Data Resolution: 30m Raster

Data Units: Number of trees per acre expressed as an equivalent density in a stand with a quadratic mean diameter of 10 inches

Creation Method: FVS generated estimates of the stand density index metric using either the Reineke 1933 or the Zeide 1983 index calculations for all trees >= 1.0" dbh based on max SDI derived from FIA plot data. Then the F3 model imputed the SDI calculations to the landscape.

2019 to 2021 Update: SDI values were adjusted for 2021 following the same procedure as outlined for density – trees per acre (described below).

Tree density values for 2021 were adjusted independently for each predefined non-overlapping diameter size class (10-inch bins) using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA = 2019\ TPA - (2019\ TPA * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree density per individual size class, depending on location.

QMD was then recalculated for 2021 using adjusted tree densities and by assigning trees in each size class to the respective mid-point diameter of that class.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: SDI_33_2021_30m.tif; SDI_83_2021_30m.tif

Proportion of Maximum SDI

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Stand density index (SDI) helps vegetation managers to identify levels of site utilization and competition to determine management scenarios to meet objectives and is often used for forest health-oriented treatments. The maximum forest stand density represents an approximate upper limit to the SDI of a site, and tree growth may be limited by competition as SDI approaches maximum SDI. This approximate upper limit on potential site SDI has been considered to be species- and site-specific by several authors using different variables to characterize the stand.

Data Resolution: 30m raster

Data Units: Proportion, 0 to 1

Creation Method: These raster data present the SDI proportion of the estimated max Stand Density Index (SDI) for both the Reineke (1933) and Zeide (1983) calculations.

2019 to 2021 Update: SDI values were adjusted for 2021 following the same procedure as outlined for density – trees per acre. Tree density values for 2021 were adjusted independently for each diameter size class (10-inch bins) using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA = 2019\ TPA - (2019\ TPA * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree density per individual size class, depending on location.

QMD was then recalculated for 2021 using adjusted tree densities and by assigning trees in each size class to the respective mid-point diameter of that class. These adjusted values for actual SDI were used to calculate percentages in combination with the max SDI values from 2019.

The maximum SDI was calculated as the 99th percentile of observed values for each of five broad climate classes. The classes were derived from the Basin Characterization Model (BCM; Flint and Flint) developed at a 270m spatial resolution. The variables (1981-2010) AET, climatic water deficit, Tmin, and Tmax were rescaled using a linear transformation to a range of 0-100 and clustered into five classes using a k-means algorithm.

Finally for each pixel, the proportion of maximum SDI is simply calculated as SDI divided by maximum SDI:

$$Proportion\_MaxSDI = SDI/MaxSDI$$

Data Source: F3 data outputs, Region 5, MARS Team

File Name: proportion_of_SDI_33_Max_30m.tif; proportion_of_SDI_83_Max_30m.tif

---

Quadratic Mean Diameter

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: Tree diameter (in inches) at breast height (dbh) for determining tree size. Quadratic mean diameter (QMD) is computed by squaring individual tree diameters, computing their average, and then taking the square root. The result is that QMD represents the diameter of the tree of the mean basal area. QMD is generally preferred over the (arithmetic) mean diameter because it is less influenced by very small trees (which can be highly variable in density from one site to the next) and it captures the fact that an inch of diameter growth means more for tree biomass on larger trees than on smaller trees.

Data Resolution: 30m raster

Data Units: Inches

Creation Method: The F3 model generated several quadratic mean diameter (QMD) raster surfaces; for all live trees (QMD_TOT) and by predefined tree size categories (QMD_x).

2019 to 2021 Update: Tree density values for 2021 were adjusted independently for each diameter size class (10-inch bins) using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA = 2019\ TPA - (2019\ TPA * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree density per individual size class, depending on location.

QMD was then recalculated for 2021 using adjusted tree densities and by assigning trees in each size class to the respective mid-point diameter of that class.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: QMD_TOT_2021_30m.tif

Canopy Veg Cover

Tier: 1

Data Vintage: 06/2020

Metric Definition and Relevance: This layer represents horizontal cover fraction occupied by tree canopies. Maps community type & fire regime, as well as available habitat for tree-dwelling species.

Data Resolution: 30m Raster

Data Units: Canopy cover is a 0-100% cover fraction and may be more precisely described as "canopy density." It calculates the proportion of all lidar returns >=5m divided by the total number of returns in that grid cell. This, therefore, does not include all vegetation, but instead describes the density of vegetation in the canopy vertical stratum (veg 5m and taller).

Creation Method: Each forest structure metric was derived directly from airborne lidar data, hosted by the USGS 3D Elevation Program. However, these data are only available for a small fraction of California's 423,970 km² area. To overcome this, we trained deep learning models—a form of pattern recognition—to identify these forest structure patterns in satellite imagery, then mapped each metric statewide.

These algorithms are of the U-net family of neural network architectures that perform pixel-wise regression and classification tasks. The satellite data includes imagery from Sentinel-1 C-band radar sensors and Sentinel-2 multispectral sensors at 10 m spatial resolution, collected in Fall 2019. Future versions will include imagery from PlanetScope multispectral sensors at 3 m resolution.

The 10m raster was resampled to 30m resolution by the RRK team.

Original datset downloaded from California Forest Observatory - Organizations - WIFIRE Commons Data Catalog (sdsc.edu). For more information, go to https://forestobservatory.com/about.html#about

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: CFO_CanopyCover2020Summer.tif

Canopy Veg Height

Tier: 1

Data Vintage: 06/2020

Metric Definition and Relevance: This layer represents distance between the ground and the top of the canopy. Canopy height is a proxy for aboveground biomass and the amount of foliage that may be consumed in a canopy fire. Since LANDFIRE doesn't support a NoData value, all NoData pixels in canopy fuel metrics were set to 0 in the Landscape files. (e.g., canopy cover was set to 0 in all NoData locations). Topographic data and surface fuel model remain unaltered.

Data Resolution: 30m Raster

Data Units: meters, min 0 - max 80; each pixel value represents the average height above ground for vegetation within that pixel

Creation Method: Each forest structure metric was derived directly from airborne lidar data, hosted by the USGS 3D Elevation Program. However, these data are only available for a small fraction of California's 423,970 km² area. To overcome this, we trained deep learning models—a form of pattern recognition—to identify these forest structure patterns in satellite imagery, then mapped each metric statewide.

These algorithms are of the U-net family of neural network architectures that perform pixel-wise regression and classification tasks. The satellite data includes imagery from Sentinel-1 C-band radar sensors and Sentinel-2 multispectral sensors at 10 m spatial resolution, collected in Fall 2019. Future versions will include imagery from PlanetScope multispectral sensors at 3 m resolution.

The 10m raster was resampled to 30m resolution by the RRK team.

Original dataset downloaded from California Forest Observatory - Organizations - WIFIRE Commons Data Catalog (sdsc.edu). For more information, go to https://forestobservatory.com/about.html#about

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: CFO_CanopyHeight2020Summer.tif

Canopy Layer Count

Tier: 1

Data Vintage: 06/2020

Metric Definition and Relevance:

This layer represents the number of distinct vertical canopy layers of trees. Vertical layer count is a proxy for leaf area index, and maps canopy complexity. Since LANDFIRE doesn't support a NoData value, all NoData pixels in canopy fuel metrics were set to 0 in the Landscape files. (e.g., canopy cover was set to 0 in all NoData locations). Topographic data and surface fuel model remain unaltered.

Data Resolution: 30m Raster

Data Units: Count

Creation Method: Each forest structure metric was derived directly from airborne lidar data, hosted by the USGS 3D Elevation Program. However, these data are only available for a small fraction of California's 423,970 km² area. To overcome this, we trained deep learning models—a form of pattern recognition—to identify these forest structure patterns in satellite imagery, then mapped each metric statewide.

These algorithms are of the U-net family of neural network architectures that perform pixel-wise regression and classification tasks. The satellite data includes imagery from Sentinel-1 C-band radar sensors and Sentinel-2 multispectral sensors at 10 m spatial resolution, collected in Fall 2019. Future versions will include imagery from PlanetScope multispectral sensors at 3 m resolution.

The 10m raster was resampled to 30m resolution by the RRK team.

Original dataset downloaded from [California Forest Observatory - Organizations - WIFIRE Commons Data Catalog (sdsc.edu)](). For more information, go to https://forestobservatory.com/about.html#about

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: CFO_CanopyLayerCount2020Summer.tif

Fine-Scale Heterogeneity

Fine-scale heterogeneity has been represented in two dimensions – as a fractal dimension of canopy cover and as a proportion of canopy cover.

Fine-Scale Heterogeneity Index

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: A key component of forest structure descriptions is the spatial heterogeneity (i.e., tree clumps and gaps), which influences vegetation growth, competition, and succession, disturbance processes, and wildlife habitat. Developing spatial heterogeneity through mechanical and prescribed fire treatments is often a goal of restoration projects and targets for the distribution of individual trees, clumps and gaps are often derived from historical estimates of stand structure.

This fractal dimension index is intended to be used in combination with the percent canopy cover as a measure of fine-scale heterogeneity. Fine-scale heterogeneity in forest structure may interrupt fuel continuity and reduce mortality of overstory trees. Fractal dimension is a measure of the complexity of shapes and ranges from 1, for simple shapes (fewer canopy interruptions), to 2, for complex shapes (more canopy interruptions). Fractal dimension is typically applied to single-part shapes, here we apply it to forest canopy within a 90m x 90m moving window.

The following diagram illustrates how fractal dimension index values correspond with spatial patterns of forest canopy coverage. Green areas denote canopy coverage and brown areas denote low-growing vegetation or bare areas. Areas where the shape of canopy coverage is more complex or patchy thereby have higher fractal area index.

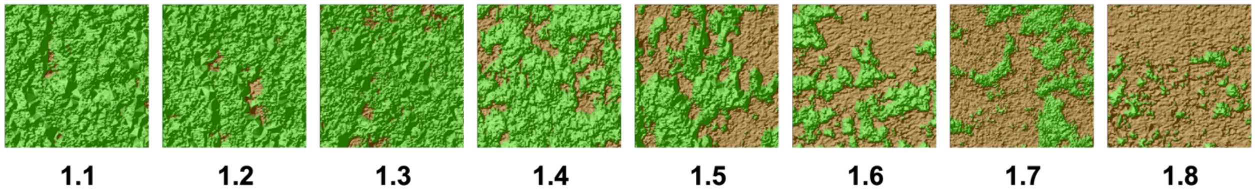

Image courtesy of Jonathan T. Kane, University of Washington.

Data Resolution: 30m raster

Data Units: Fractal dimension index, 1 to 2

Creation Method: The metric is derived from 3m resolution PhoDAR estimates of spring 2020 canopy height produced by Salo Sciences. Pixels with height greater than 2m were classified as canopy; pixels with height less than or equal to 2m were classified as canopy gaps. Fractal dimension index was calculated within a 90m (900-pixel) moving window using the following expression, applicable to shapes represented by rectilinear pixels (McGarigal and Marks 1995).

$$2*\ln(p/4)/\ln(a)$$

Where a and p are, respectively, the area and perimeter of forest canopy (height > 2m) within the moving window.

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: fractal_dim_spring_2020_30m.tif

Percent Canopy Cover

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: This percent canopy cover is intended to be used in combination with the fractal dimension index as a measure of fine-scale heterogeneity.

Data Resolution: 30m raster

Data Units: Percent

Creation Method: The metric is derived from 3m resolution PhoDAR estimates of spring 2020 canopy height produced by Salo Sciences. Pixels with height greater than 2m were classified as canopy; pixels with height less than or equal to 2m were classified as canopy gaps.

Data Source: California Forest Observatory (Salo Sciences), 2020

File Name: perc_canopy_cover_spring_2020_30m.tif

Composition

The composition of a forest is a reference to the biodiversity of the landscape; this includes a diversity of vegetation species, types (e.g., trees, shrubs, forbs, etc.), and distribution. Tree species composition affects many aspects of forest dynamics and function. A diversity of tree and shrub species can confer greater resilience to climate change and beetle outbreaks. The vegetation composition also affects fire dynamics, water reliability, carbon pools and sequestration, and economic diversity pillars. Since European settlement and the adoption of fire suppression and logging, forests of the Sierra Nevada shifted to increased dominance of shade-tolerant and fire-intolerant species like white fir and red fir, incense cedar, Douglas fir, and tanoak. Other species like ponderosa pine, Jeffrey pine, sugar pine, and black oak, which are more shade-intolerant and fire-tolerant, declined in coverage. With increasingly larger and higher-severity fire occurring, forest-cover loss may be significant and shrub cover will increase.

Tree Cover

Tier: 1

Data Vintage: 12/2021

Metric Definition and Relevance: Total tree cover as measured by the fractional non-overlapping absolute tree cover, viewed vertically. Provides a first order measure of vegetation type when combined with parallel observations of shrub and herbaceous cover. Data from the National Land Cover Database (NLCD) are used for training, and NLCD definitions for cover (for example, the distinction between tree vs shrub) are expected to be similar in the CECS data sets.

Data Resolution: 30m Raster

Data Units: Fractional non-overlapping absolute cover; continuous variable from 0 to 1.

Creation Method: Machine learning (Random Forest) using the National Land Cover Database for training and Landsat observations as predictors. See https://doi.org/10.1029/2021AV000654 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: VegCover_Tree_2021.tif

Shrub Cover

Tier: 1

Data Vintage: 12/2021

Metric Definition and Relevance: Total shrub cover as measured by the fractional non-overlapping absolute shrub cover, viewed vertically. Provides a first order measure of vegetation type when combined with parallel observations of tree and herbaceous cover. Data from the National Land Cover Database (NLCD) are used for training, and NLCD definitions for cover (for example, the distinction between tree vs shrub) are expected to be similar in the CECS data sets.

Data Resolution: 30m Raster

Data Units: Fractional non-overlapping absolute cover; continuous variable from 0 to 1.

Creation Method: Machine learning (Random Forest) using the National Land Cover Database for training and Landsat observations as predictors. See https://doi.org/10.1029/2021AV000654 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: VegCover_Shrub_2021.tif

Herbaceous Cover

Tier: 1

Data Vintage: 12/2021

Metric Definition and Relevance: Total herbaceous cover as measured by the fFractional non-overlapping absolute herbaceous cover, viewed vertically. Provides a first order measure of vegetation type when combined with parallel observations of tree and herbaceous cover. Data from the National Land Cover Database (NLCD) are used for training, and NLCD definitions for cover (for example, the distinction between tree vs shrub) are expected to be similar in the CECS data sets.

Data Resolution: 30m Raster

Data Units: Fractional non-overlapping absolute cover; continuous variable from 0 to 1.

Creation Method: Machine learning (Random Forest) using the National Land Cover Database for training and Landsat observations as predictors. See https://doi.org/10.1029/2021AV000654 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: VegCover_Herb_2021.tif

Seral Stage

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The seral stages are categories that represent the developmental progression of forest ecosystems from initial establishment or following a stand replacing event (e.g., high severity fire) to a forest dominated by trees in the upper age classes for a given forest type. Late seral forests are also often characterized by multiple ages of forest trees and dead and dying trees in some form of equilibrium. Seral conditions across landscapes were highly variable prior to major European settlement in the western US. These patterns were highly attuned to dominant disturbance regimes and the multi-scaled variability in environmental conditions across topographic and climatic gradients. These patterns helped to reinforce fire regimes dominated by low- to moderate-severity fire across much of the region and provided for multiple habitat requirements for a wide variety of species.

Data Resolution: 30m raster

Data Units: Categorical 1 - 3 (seral stages), continuous variable 0-1 representing percentage of a HUC (early and late seral stage)

Creation Method: The limitations imposed by FVS allow for the CWHR classification to be used by the F3 model, however the seral stages for forested lands had to be binned into one of three categories (Early, Mid, Late) and those are defined by tree diameter, per the CWHR system.

Size Class	Size (inches DBH)	Seral Stage
1 Seedling	less than 1	Early (1)
2 Sapling	1 – 6	Early (1)
3 Pole	6 – 11	Mid (2)
4 Small	11 – 24	Mid (2)
5 Medium to Large	24+	Late (3)
6 Multi-storied	36 – 48	Late (3)

Late Seral conditions have been lumped into a single classification (24” and up). Early and late seral stage conditions were evaluated (separately) at the HUC12-scale (10,000-30,000 ac) as these patterns can be highly variable at finer-scales. For each HUC12, the proportion of the watershed covered by the evaluated seral stage has been calculated.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: SeralStage_EML_2021.tif; early_SeralStage_prop.tif; late_SeralStage_prop.tif

Disturbance

Sierra forests evolved with a suite of frequent disturbances: wildfires (both from lightning and burning by indigenous people), bark beetle-caused mortality, drought-caused mortality, avalanches, landslides, and windthrow, all of which created forest heterogeneity across the landscape. This heterogeneity included variations in surface and ladder fuels, which moderated fire behavior and spread. The variations in stand density and forest opening also served as critical habitats for wildlife. Forested areas are now more homogeneous due to lack of disturbance. The lack of disturbance is evident in the forest structure.

Time Since Last Disturbance

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The metric for time since disturbance ("tsd") was measured as time in years before 2021 since the most recent disturbance of at least 25% canopy cover loss per 30m pixel as defined by eDaRT Mortality Magnitude Index (MMI) layers. MMI values less than 25% were not considered.

The most recent disturbance class ("dist_class") of the most recent disturbance of 25% magnitude or greater detected by eDaRT and were prioritized in the order: fire (1), treatment (2), eDaRT (3). For example, if a pixel intersected a fire perimeter and a treatment polygon, that pixel would be assigned a code of 1 (fire) rather than 2 (treatment). Note that while the occurrence of and magnitude of a disturbance was determined using eDaRT, disturbance class was determined first using fire perimeters and FACTS activities, with remaining eDaRT disturbances collectively assigned to insect- and disease-related tree mortality.

Data Resolution: 30m raster

Data Units: Years

Creation Method: Layers representing time since disturbance, most recent disturbance magnitude, and most recent disturbance class were produced using the Ecosystem Disturbance and Recovery Tracker (eDaRT), Forest Activities (FACTS) and CAL FIRE Timber Harvesting Plan (THP) databases, and the CAL FIRE Fire and Resource Assessment Program (FRAP) fire perimeter dataset. All layers are complete for the entire area within the 300s and 400s eDaRT scenes as well as for scenes 103, 105, and 501. The reference year was set to 2021 since fire history and eDaRT only reported up through 2020. The earliest year assessed was 2010 since eDaRT data prior to 2010 was used for model training and is not reliable.

Data Source: Caden Chamberlain, Environmental and Forest Sciences, University of Washington

File Name: TSD_2021.tif

Tree Mortality – Past 5 Years and Past 1 year

Tier: 2

Data Vintage: 2021

Metric Definition and Relevance: The dead tree canopy cover fraction change from the Mortality Magnitude Index (MMI) for eDaRT events. This metric is provided to complement data (in terms of spatial resolution and canopy cover loss estimates) available from the Region 5 Insect and Disease Survey that performs aerial detection monitoring in support of tracking tree mortality that includes affected hosts and agents (available at: https://www.fs.usda.gov/detail/r5/forest-grasslandhealth/?cid=fsbdev3_046696).

Data Resolution: 30m raster

Data Units: Percent of 30m pixel (absolute, not relative, value)

Creation Method: Insect- and disease-caused tree mortality was compiled at the 30 m scale from the Ecosystem Disturbance and Recovery Tracker (eDaRT; Koltunov et al. 2020), described in the Introduction. This metric represents the 2021 status of cumulative tree mortality occurring over the years 2017 to 2021. An additional version represents the mortality of the last 1 year (2021). Note that tree mortality which, since its occurrence, was affected by fire or land management activities has been removed.

Data Source: Region 5, MARS Team

File Name: Mortality_MMI_2017_2021.tif; Mortality_MMI_2021.tif

Cumulative Tree Cover Loss

Tier: 1

Data Vintage: 12/2020

Metric Definition and Relevance: The cumulative loss of tree cover over a 30-year period (1992-2020). Tree cover loss reflects fires, harvest/management and dieoff. Only disturbances that are sufficient to trigger the Continuous Change Detection and Classification algorithm are included; low-level, diffuse dieoff is likely missed.

Data Resolution: 30m Raster

Data Units: Cumulative fractional non-overlapping absolute tree cover loss, where tree cover is a continuous variable from 0 to 1. Cumulative loss can exceed 1 in cases with multiple disturbances.

Creation Method: Vegetation disturbances were identified over the Landsat TM/ETM+/OLI era using the Continuous Change Detection and Classification algorithm (CCDC). The corresponding annual change in tree cover was determined with machine learning (Random Forest) using the National Land Cover Database for training and Landsat/CCDC observations as predictors; this produced a ~35-year stack of rasters that identified the locations and severity of tree cover loss. This stack was then summed for 1992-2020 to calculate the cumulative tree cover loss over a 30-year period. See https://doi.org/10.1029/2021AV000654 for further information.

CECS data that reflect landscape changes resulting from disturbances require 6 to 12 months of Landsat observations **after a given year that included major disturbances (such as a high severity wildfire)** to fully quantify that disturbance. CECS data that reflect disturbance, such as this data layer, are therefore available **through water year 2020 (i.e. through September 2020)**.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: DistHist_Severe_Tree_19912020.tif

Cumulative Shrub Cover Loss

Tier: 1

Data Vintage: 12/2020

Metric Definition and Relevance: The cumulative loss of shrub cover over a 30-year period (1992-2020). Shrub cover loss reflects fires, harvest/management and dieoff. Only disturbances that are sufficient to trigger the Continuous Change Detection and Classification algorithm are included; low-level, diffuse dieoff is likely missed.

Data Resolution: 30m Raster

Data Units: Cumulative fractional non-overlapping absolute shrub cover loss, where shrub cover is a continuous variable from 0 to 1. Cumulative loss can exceed 1 in cases with multiple disturbances.

Creation Method: Vegetation disturbances were identified over the Landsat TM/ETM+/OLI era using the Continuous Change Detection and Classification algorithm (CCDC). The corresponding annual change in shrub cover was determined with machine learning (Random Forest) using the National Land Cover Database for training and Landsat/CCDC observations as predictors; this produced a ~35-year stack of rasters that identified the locations and severity of shrub cover loss. This stack was then summed for 1992-2021 to calculate the cumulative tree cover loss over a 30-year period. See https://doi.org/10.1029/2021AV000654 for further information.

CECS data that reflect landscape changes resulting from disturbances require 6 to 12 months of Landsat observations **after a given year that included major disturbances (such as a high severity wildfire)** to fully quantify that disturbance. CECS data that reflect disturbance, such as this data layer, are therefore available **through water year 2020 (i.e. through September 2020)**.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: DistHist_Severe_Shrub_19912020.tif

Risk of Tree Dieoff During Drought

Tier: 1

Data Vintage: 12/2021

Metric Definition and Relevance: A quantitative continuous variable that reflects the risk of tree dieoff during a significant drought period (SPI48 drought = -2).

Data Resolution: 30m Raster

Data Units: This is a dimensionless index that ranges from 0 to ~20000. Low values indicate minimal or no risk of tree dieoff during drought, either or both because there are few trees in the pixel and/or there is ample local moisture even during periods of extreme precipitation shortfall. High values indicate significant risk of tree dieoff during drought, as a result of both a high density of trees at the site and likelihood of extreme local moisture shortfall.

Creation Method: Calculated by combining information on the local moisture balance and tree density. Local moisture balance was calculated as the ratio of Annual Evapotranspiration with the canopy observed in 2021 to Precipitation during a SPI 48 drought = -2 based on local P observations during 1991-2020. This ratio quantifies the local moisture deficit/surplus that would be expected during a 48-month period with precipitation that is 2 standard deviations below the local 30 year Normal. Tree cover was determined from Landsat. See https://doi.org/10.1038/s41561-019-0388-5 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: Vulner_TreeDieoff_SPI_2_2021.tif

Potential Climate Refugia -Baseline (Historical) Conditions

Tier: 3

Data Vintage: 2016

Metric Definition and Relevance: This raster dataset represents habitat types (natural vegetation communities) and their distribution across the array of climate conditions that each separate habitat type is found in under the baseline climate conditions. A 2015 map of the state's natural vegetation compiled from multiple sources was classified to the National Vegetation Classification Standard's mid-level classification, called "Macrogroup". Thirty one natural vegetation macrogroups are identified in the map, covering 99.87% of the state's natural terrestrial vegetation, and occupying 353,271 km2.

This serves as the foundation from which habitat types will be exposed to predicted changes in climate. Data are arrayed across 0 to 1 in terms of their exposure to current climate conditions. This data layer provides a baseline of vegetation adapted to "historic" conditions; i.e. climate conditions from the recent past; 1980-2010.

Data Resolution: 270m Raster

Data Units: 0- 1. Low values indicate higher resilience to threats. High values indicate significant exposure to climate change. -1 represents 'non analog' areas, i.e. locations that are outside the historic climate envelope of a given vegetation type.

Creation Method: The vegetation climate exposure analysis takes advantage of the 2015 vegetation map compiled for California by CALFIRE. Each Macrogroup (MG) was analyzed to determine which California habitats and associated dominant plant species make up its definition. California habitats are defined by the California Department of Fish and Wildlife (CDFW) through their California Wildlife Habitat Relationship (WHR) models9. WHR types are made up of plant species, such as the dominant trees, shrubs, and smaller plants. CDFW experts determined which WHR types correspond to each individual macrogroup; this cross-walk was used to develop a list of the dominant plant species that comprise each macrogroup.

The climate space occupied by each distinct vegetation macrogroup (largely equivalent to a CWHR habitat type) from the current time period was identified. This was done by using the points for each type and applying a kernel density estimator on a 2-d surface composed of the first two principal components of the climate conditions. The result is a smoothed continuous point density surface, showing the prevalence of each vegetation type across the range of sampled climatic conditions. This surface was partitioned by fitting contour lines so that they enclose a proportion of the original points from the current time period. Contours were calculated at 5% increments. For example the innermost 5% contour line encloses the 5% of pixels for the given vegetation type which are at the core of the climate space for that type, as determined by its density in the climate space. Cells further away from the dense central core, are considered to be more marginal in the vegetation type's distribution. The outer contours are fit to enclose the 95-99% of climatically marginal points, with the last 1% of cells (beyond the 99% contour) being the most marginal. In addition, if a cell lies outside the space defined by the 99% contour of any vegetation type, it is considered to be "non-analog," which means that it experiences climatic conditions outside of the conditions where we have a good sample in the initial time period. Excluded from this assessment are non-vegetated types such as snow, open water, and ice; and non-natural landcover types mapped as vineyards, tilled earth, orchards and Urban.

For more information on methods for the development of these climate refugia data see:

Thorne et al. 2015

Thorne et al. 2016

Thorne et al. 2017

Thorne et al. 2020

Data Source: Information Center for the Environment, UC Davis

File Name: hst8110.tif

Potential Climate Refugia - under Modeled Climate Change (MIROC model - hotter and drier)

Tier: 3

Data Vintage: 2016

Metric Definition and Relevance: This raster dataset represents habitat types (CWHR habitat classes) and their predicted exposure to climate stress across the array of predicted climate conditions (separate layers for early (2010 - 2039), mid (2040-2069), and late century (2070-2099)) for all habitat types in comparison to the baseline climate conditions. This serves as the foundation from which habitat types will be exposed to predicted changes in climate. Data are arrayed across 0 to 1 in terms of their exposure to current climate conditions. These three data layers can be used to help land managers allocate limited resources for climate-adaptive field work by providing a view of climate risk that varies across the lands they manage.

The Climate Change Model used in this analysis is the Miroc Earth System Model. This ESM, named "MIROC-ESM", is based on a global climate model MIROC (Model for Interdisciplinary Research on Climate) which has been cooperatively developed by researchers in Japan and others. This model suggests a hotter and drier future. The emission scenario used is the RCP 8.5, which represents a range of warming statewide from 1.99 to 4.56°C and between a 24.8% decrease in precipitation and a 22.9% increase, respectively.

Data Resolution: 270m Raster

Data Units: 0- 1. Low values indicate higher resilience to threats. High values indicate significant exposure to climate change. -1 represents 'non analog' areas, i.e. locations that are outside the historic climate envelope of a given vegetation type.

Creation Method: The vegetation climate exposure analysis takes advantage of the 2015 vegetation map compiled for California, which is described above. The vegetation climate exposure model is implemented in the R programming language, and takes the vegetation and climate raster files as the primary input data. The values of the climate raster files were randomly sampled at 100,000 points on the landscape, which were used to fit a statistical model characterizing the relationship between the variables both in the current time and for the modeled future data.

At each of these 100,000 points, 9 hydro-climatic variables were sampled to characterize the range and variation of conditions in the study region. These variables were: annual mean minimum temperature (Tmin), annual mean maximum temperature (Tmax), annual precipitation (PPT), actual evapotranspiration (AET), potential evapotranspiration (PET), climatic water deficit (CWD), snowpack depth on April 1st, runoff, and recharge. The variation between these variables was modeled using a principal component analysis21 (PCA) to identify the dominant components of variation. The top-two principal components axes, representing about 79% of the variability across the four climate projections, were extracted as a two-dimensional space, and are portrayed as the axes for the PCA plots shown in each macrogroup chapter below. This was done to simplify the representation of the climate space, while maintaining the most important information on the variables to be associated with the observed vegetation distributions.

The climate space occupied by each distinct macrogroup from the current time period was identified. This was done by using the points for each type and applying a kernel density estimator on a 2-d surface composed of the first two principal components of the climate conditions. The result is a smoothed continuous point density surface, showing the prevalence of each vegetation type across the range of sampled climatic conditions. This surface was partitioned by fitting contour lines so that they enclose a proportion of the original points from the current time period. Contours were calculated at 5% increments. For example the innermost 5% contour line encloses the 5% of pixels for the given vegetation type which are at the core of the climate space for that type, as determined by its density in the climate space. Cells further away from the dense central core, are considered to be more marginal in the vegetation type's distribution. The outer contours are fit to enclose the 95-99% of climatically marginal points, with the last 1% of cells (beyond the 99% contour) being the most marginal. In addition, if a cell lies outside the space defined by the 99% contour of any vegetation type, it is considered to be "non-analog," which means that it experiences climatic conditions outside of the conditions where we have a good sample in the initial time period. As a result, the status of that point is uncertain. There are occasionally a few extreme points which appear to be far outside the general distribution for the type. These may be due to misclassified vegetation types in the source data, microclimatic conditions not captured by the climate data, historic anomalies in long-lived species, etc.

Climate exposure is the level of climate change expected in the areas where each macrogroup is dominating. This report uses the term "vegetation climate exposure analysis" to describe the following analysis which was conducted on each macrogroup. The vegetation climate exposure analysis is calculated using the mapped extent of each macrogroup. Every grid cell of each macrogroup was ranked as to its level of exposure, relative to the entire area of that macrogroup. This was done for the current time, and used to define the common climate found for each macrogroup. Once each type's "climate envelope" was defined, we then assessed how much every grid cell changed under various future climate projections. This allowed a measure of the vegetation stress, or climate exposure. The area extent of each macrogroup that will be lost from the most commonly occurring climate conditions (≤80%) and the area that will fall into current marginal, or stressed, climate conditions (>95%) or outside the current climate conditions was calculated. This approach is particularly useful for resource managers, who often are constrained to work in specified areas, and need estimates of what areas within their jurisdiction are likely to be highly stressed, and what areas are likely to be less stressed, in effect climate refuge areas.

To consider how refugial conditions from a range of stressors can inform conservation planning and management, the authors integrated metrics of refugial capacity across different domains, which are defined as social, ecological, or physical drivers, processes, or cycles that influence landscape structure, function, or composition. To persist in the California landscape, species and ecosystems may need refugia from shifting climatic conditions, including extremely hot summers and prolonged droughts, but non-climate stressors can also affect conservation outcomes. In this landscape, changes in fire frequency can be a significant stressor affecting plant community structure and persistence. Anthropogenic features that modify hydrologic flows alter the ability of watersheds to sustain functional habitats. And finally, protected areas are often designed to mitigate the impacts of anthropogenic activities; however, recreational activities may alter the refugial capacity of the protected land, affecting the ability of the landscape to sustain species and their habitats. We combined these individual metrics to assess landscape level refugial capacity.

Sites with high refugial capacity (super-refugia sites) have, on average, 30% fewer extremely warm summers, 20% fewer fire events, 10% less exposure to altered river channels and riparian areas, and 50% fewer recreational trails than the surrounding landscape. Our results suggest that super-refugia sites (~8,200 km2) for some natural communities are underrepresented in the existing protected area network, a finding that can inform efforts to expand protected areas.

For more information on methods for the development of these climate refugia data see:

Thorne et al. 2015

Thorne et al. 2016

Thorne et al. 2017

Thorne et al. 2020

Data Source: Information Center for the Environment, UC Davis

File Name: miroc_85_1039.tif; miroc_85_4069.tif; miroc_85_7099.tif

Potential Climate Refugia - Combined Modeled Climate Change (MIROC model - (Hotter and drier) and CNRM-CM5 (wetter and warmer)

Tier: 3

Data Vintage: 2016

Metric Definition and Relevance: This raster dataset represents habitat types (Macro Veg Type, largely equivalent to CWHR habitat classes) and their predicted exposure to climate stress across the array of predicted climate conditions (separate layers for early (2010 - 2039), mid (2040-2069), and late century (2070-2099)) for all habitat types in comparison to the baseline climate conditions. This serves as the foundation from which habitat types will be exposed to predicted changes in climate. Data are arrayed across 0 to 1 in terms of their exposure to current climate conditions. These three data layers can be used to help land managers allocate limited resources for climate-adaptive field work by providing a view of climate risk that varies across the lands they manage.

This analysis uses both the Miroc Earth System Model and the CNRM-CM5. CNRM-CM5 is an Earth system model designed to run climate simulations. It consists of several existing models designed independently and coupled through the OASIS software. Both were used under the RCP 8.5 emission scenario given that this is more likely under current emission levels.

This data layer is provided as a summary of likely exposure results. Exposure Scores:

- · 1 = Refugia: CNRM-CM5 only (CNRM exposure values < 80%)
- · 2 = Refugia: MIROC-ESM only (MIROC exposure values < 80%)
- · 3 = Refugia Consensus (both models agree exposure values < 80%)
- · **8 = High Exposure (both models agree exposure values >95%)**
- · **9 = Very High Exposure (both models agree exposure values >99%)**

Data Resolution: 270m Raster

Data Units: 0, 1, 2, 3, 8, 9 Low values indicate higher resilience to threats. High values indicate significant exposure to climate change. -1 represents 'non analog' areas, i.e. locations that are outside the historic climate envelope of a given vegetation type.

Creation Method: Each dominant species is scored for its sensitivity to, and ability to adapt (adaptive capacity) to climate change. Sensitivity refers to the degree to which changes in climate are thought to directly impact different species. Adaptive capacity refers to estimates of the degree to which different species can use their life history characteristics to moderate impacts from changing climate. These two sets of scores represent the biological attributes of the dominant species in each macrogroup. We scored each of the dominant species comprising each macrogroup, according to life history characteristics defined in attribute tables of the California Manual of Vegetation, and supplemented by information found in the USDA plants database and the Jepson Interchange, a web portal for California plant taxonomy. The scores were combined to generate a single sensitivity and adaptive capacity (S&A) score.

Climate exposure is the level of climate change expected in the areas where each macrogroup is dominating. This report uses the term "vegetation climate exposure analysis" to describe the following analysis which was conducted on each macrogroup. The vegetation climate exposure analysis is calculated using the mapped extent of each macrogroup. Every grid cell of each macrogroup was ranked as to its level of exposure, relative to the entire area of that macrogroup. This was done for the current time, and used to define the common climate found for each macrogroup. Once each type's "climate envelope" was defined, we then assessed how much every grid cell changed under various future climate projections. This allowed a measure of the vegetation stress, or climate exposure. The area extent of each macrogroup that will be lost from the most commonly occurring climate conditions (≤80%) and the area that will fall into current marginal, or stressed, climate conditions (>95%) or outside the current climate conditions was calculated. This approach is particularly useful for resource managers, who often are constrained to work in specified areas, and need estimates of what areas within their jurisdiction are likely to be highly stressed, and what areas are likely to be less stressed, in effect climate refuge areas.

To consider how refugial conditions from a range of stressors can inform conservation planning and management, the authors integrated metrics of refugial capacity across different domains, which are defined as social, ecological, or physical drivers, processes, or cycles that influence landscape structure, function, or composition. To persist in the California landscape, species and ecosystems may need refugia from shifting climatic conditions, including extremely hot summers and prolonged droughts, but non-climate stressors can also affect conservation outcomes. In this landscape, changes in fire frequency can be a significant stressor affecting plant community structure and persistence. Anthropogenic features that modify hydrologic flows alter the ability of watersheds to sustain functional habitats. And finally, protected areas are often designed to mitigate the impacts of anthropogenic activities; however, recreational activities may alter the refugial capacity of the protected land, affecting the ability of the landscape to sustain species and their habitats. We combined these individual metrics to assess landscape level refugial capacity.

Sites with high refugial capacity (super-refugia sites) have, on average, 30% fewer extremely warm summers, 20% fewer fire events, 10% less exposure to altered river channels and riparian areas, and 50% fewer recreational trails than the surrounding landscape. Our results suggest that super-refugia sites (~8,200 km2) for some natural communities are underrepresented in the existing protected area network, a finding that can inform efforts to expand protected areas.

For more information on methods for the development of these climate refugia data see:

Thorne et al. 2015

Thorne et al. 2016

Thorne et al. 2017

Thorne et al. 2020

Data Source: Information Center for the Environment, UC Davis

File Name: combine85_all7.tif

Social and Cultural Well-Being

The landscape provides a place for people to connect with nature, recreate, to maintain and improve their overall health, and an opportunity to contribute to environmental stewardship. While the elements of this pillar include public health and engagement, recreation quality, and equitable opportunities producing quantifiable, measurable and actionable metrics remains challenging. These metrics are still under development and insights into these potential metrics are appreciated.

DESIRED OUTCOME: The landscape provides a place for people to connect with nature, to recreate, to maintain and improve their overall health, and to contribute to environmental stewardship, and is a critical component of their identity.

Environmental Opportunity

Environmental Opportunity is the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income regarding the development, implementation and enforcement of environmental laws, regulations, policies and land management.

American Indian or Alaska Native race alone Population Concentration

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: Relative concentration of the Sierra Nevada region's American Indian population. The variable AIAN_ALN_AND_MULTIRACE includes BOTH individuals who select American Indian or Alaska Native as their sole racial identity (they *only* identify as American Indian), AND individuals who select American Indian / Alaska Native as one of two or more racial identities (they *partly* identify as American Indian) in response to the Census questionnaire. IMPORTANT: this self reported ancestry and Tribal membership are distinct identities and one does not automatically imply the other. These data should not be interpreted as a distribution of "Tribal people."

"Relative concentration" is a measure that compares the proportion of population within each Census block group data unit that identify as American Indian / Alaska Native alone to the proportion of all people that live within the 775 block groups in the Sierra Nevada RRK region that identify as American Indian / Alaska native alone. Example: if 5.2% of people in a block group identify as AIANALN, the block group has twice the proportion of AIANALN individuals compared to the Sierra Nevada RRK region (2.6%), and more than three times the proportion compared to the entire state of California (1.6%). If the local proportion is twice the regional proportion, then AIANALN individuals are highly concentrated locally.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 0: *Zero or nearly zero*. The variable is absent (observed value = 0) or is very low; the local proportion of the subject population variable is 10% or less than the same proportion in the Sierra Nevada region population in total

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks,if exceptional outliers are present, but is typically over 6 times (600%)

- Class Code 8: *Exceptionally high.* The subject population concentration is so high that it is an exceptional outlier; the local proportion of the subject population variable is typically greater than 6 or 7 times that of the corresponding proportion in the region

- Class Code 99: *Unclassifiable.* The 90% confidence interval for the estimate is wide enough to cause the values to span four or more classes. In these cases, it is impossible to say with any reasonable certainty whether the concentration is "low" or "high."

Creation Method: Data reporting units are Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks 3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Note; 1) The pixels attributed with a categorical data unit describing the relative concentration of AIAN_ALN_AND_MULTIRACE population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data Source: U.S. Department of Commerce, Census Bureau, 2020 Decennial Census Redistricting File (PL 94-171).

Racial identity data are reported in Table P1 of the PL 94-171 release. Population counts were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units above).

File Name: AmericanIndian_2020.tif

Hispanic/Latino Population Concentration

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: Relative concentration of the Sierra Nevada region's Hispanic/Latino population. The variable HISPANIC records all individuals who select Hispanic or Latino in response to the Census questionnaire, regardless of their response to the racial identity question.

"Relative concentration" is a measure that compares the proportion of population within each Census block group data unit that identify as American Indian / Alaska Native alone to the proportion of all people that live within the 775 block groups in the Sierra Nevada RRK region that identify as American Indian / Alaska native alone. Example: if 5.2% of people in a block group identify as HISPANIC, the block group has twice the proportion of HISPANIC individuals compared to the Sierra Nevada RRK region (2.6%), and more than three times the proportion compared to the entire state of California (1.6%). If the local proportion is twice the regional proportion, then HISPANIC individuals are highly concentrated locally.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 0: *Zero or nearly zero*. The variable is absent (observed value = 0) or is very low; the local proportion of the subject population variable is 10% or less than the same proportion in the Sierra Nevada region population in total

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks,if exceptional outliers are present, but is typically over 6 times (600%)

Creation Method: Data reporting units are Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks 3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Note; 1) The pixels attributed with a categorical data unit describing the relative concentration of HISPANIC population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data were derived from the 2020 Census Total population for the block group from the redistricting file (PL 94-171) of the 2020 Census, released summer 2021. The raw data were obtained directly from the Census Bureau data set table named in "Origin"; all data sets downloaded from census.data.gov and joined to TIGER Census block group features. There are 775 Census block groups within or intersecting the Sierra Nevada RRK region boundary.

Data Source: U.S. Department of Commerce, Census Bureau, 2020 Decennial Census Redistricting File (PL 94-171).

Racial identity data are reported in Table P1 of the PL 94-171 release. Population counts were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units above).

File Name: Hispanic_2020.tif

Hispanic and/or Black, Indigenous or person of color (HSPBIPOC)

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: Relative concentration of the Sierra Nevada region's Hispanic and/or Black, Indigenous or person of color (HSPBIPOC) population. The variable HSPBIPOC is equivalent to all individuals who select a combination of racial and ethnic identity in response to the Census questionnaire EXCEPT those who select "not Hispanic" for the ethnic identity question, and "white race alone" for the racial identity question. This is the most encompassing possible definition of racial and ethnic identities that may be associated with historic underservice by agencies, or be more likely to express environmental justice concerns (as compared to predominantly non-Hispanic white communities). Until 2021, federal agency guidance for considering environmental justice impacts of proposed actions focused on how the actions affected "racial or ethnic minorities." "Racial minority" is an increasingly meaningless concept in the USA, and particularly so in California, where only about 3/8 of the state's population identifies as non-Hispanic and white race alone - a clear majority of Californians identify as Hispanic and/or not white. Because many federal and state map screening tools continue to rely on "minority population" as an indicator for flagging potentially vulnerable / disadvantaged/ underserved populations, our analysis includes the variable HSPBIPOC which is effectively "all minority" population according to the now outdated federal environmental justice direction. A more meaningful analysis for the potential impact of forest management actions on specific populations considers racial or ethnic populations individually: e.g., all people identifying as Hispanic regardless of race; all people identifying as American Indian, regardless of Hispanic ethnicity; etc.

"Relative concentration" is a measure that compares the proportion of population within each Census block group data unit that identify as HSPBIPOC alone to the proportion of all people that live within the 775 block groups in the Sierra Nevada RRK region that identify as HSPBIPOC alone. Example: if 5.2% of people in a block group identify as HSPBIPOC, the block group has twice the proportion of HSPBIPOC individuals compared to the Sierra Nevada

RRK region (2.6%), and more than three times the proportion compared to the entire state of California (1.6%). If the local proportion is twice the regional proportion, then HSPBIPOC individuals are highly concentrated locally.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks,if exceptional outliers are present, but is typically over 6 times (600%)

Creation Method: Data reporting units are Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks 3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the

Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Note; 1) The pixels attributed with a categorical data unit describing the relative concentration of HSPBIPOC population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data were derived from the 2020 Census Total population for the block group from the redistricting file (PL 94-171) of the 2020 Census, released summer 2021. The raw data were obtained directly from the Census Bureau data set table named in "Origin"; all data sets downloaded from census.data.gov and joined to TIGER Census block group features. There are 775 Census block groups within or intersecting the Sierra Nevada RRK region boundary.

Data Source: U.S. Department of Commerce, Census Bureau, 2020 Decennial Census Redistricting File (PL 94-171).

Racial identity data are reported in Table P1 of the PL 94-171 release. Population counts were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units above)

File Name: HSPBIPOC_2020.tif

Asian Population Concentration

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: Relative concentration of the Sierra Nevada region's Asian American population. The variable ASIANALN records all individuals who select Asian as their SOLE racial identity in response to the Census questionnaire, regardless of their response to the Hispanic ethnicity question. Both Hispanic and non-Hispanic in the Census questionnaire are potentially associated with the Asian race alone.

"Relative concentration" is a measure that compares the proportion of population within each Census block group data unit that identify as ASIANALN alone to the proportion of all people that live within the 775 block groups in the Sierra Nevada RRK region that identify as ASIANALN alone. Example: if 5.2% of people in a block group identify as HSPBIPOC, the block group has twice the proportion of ASIANALN individuals compared to the Sierra Nevada RRK region (2.6%), and more than three times the proportion compared to the entire state of California (1.6%). If the local proportion is twice the regional proportion, then ASIANALN individuals are highly concentrated locally.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 0: *Zero or nearly zero*. The variable is absent (observed value = 0) or is very low; the local proportion of the subject population variable is 10% or less than the same proportion in the Sierra Nevada region population in total

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks,if exceptional outliers are present, but is typically over 6 times (600%)

- Class Code 8: *Exceptionally high.* The subject population concentration is so high that it is an exceptional outlier; the local proportion of the subject population variable is typically greater than 6 or 7 times that of the corresponding proportion in the region

- Class Code 99: *Unclassifiable.* The 90% confidence interval for the estimate is wide enough to cause the values to span four or more classes. In these cases, it is impossible to say with any reasonable certainty whether the concentration is "low" or "high."

Creation Method: Data reporting units are Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks 3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Note; 1) The pixels attributed with a categorical data unit describing the relative concentration of ASIANALN population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data were derived from the 2020 Census Total population for the block group from the redistricting file (PL 94-171) of the 2020 Census, released summer 2021. The raw data were obtained directly from the Census Bureau data set table named in "Origin"; all data sets downloaded from census.data.gov and joined to TIGER Census block group features. There are 775 Census block groups within or intersecting the Sierra Nevada RRK region boundary.

Data Source: U.S. Department of Commerce, Census Bureau, 2020 Decennial Census Redistricting File (PL 94-171).

Racial identity data are reported in Table P1 of the PL 94-171 release. Population counts were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units above)

File Name: Asian_2020.tif

Multi-Race, Except Part-American Indian Population Concentration

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: The Relative concentration of the Sierra Nevada region's population that identifies as "Multiracial", EXCEPT those with part-American Indian identity, in response to the Census questionnaire. "Relative concentration" is a measure that compares the proportion of population within each Census block group data unit that identifies as Multiiracial to the proportion of all people that live within the 775 census block groups in the Sierra Nevada RRK region. People with part-American Indian identity are not included here but are included in the American Indian or Alaska Native Race Alone and Multirace Population, described above.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 0: *Zero or nearly zero*. The variable is absent (observed value = 0) or is very low; the local proportion of the subject population variable is 10% or less than the same proportion in the Sierra Nevada region population in total

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks,if exceptional outliers are present, but is typically over 6 times (600%)

- Class Code 99: *Unclassifiable.* The 90% confidence interval for the estimate is wide enough to cause the values to span four or more classes. In these cases, it is impossible to say with any reasonable certainty whether the concentration is "low" or "high."

Creation Method: Data reporting units are Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks 3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Note: 1) The pixels attributed with a categorical data unit describing the relative concentration of AIAN_ALN_AND_MULTIRACE_2020 population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data were derived from the 2020 Census Total population for the block group from the redistricting file (PL 94-171) of the 2020 Census, released summer 2021. The raw data were obtained directly from the Census Bureau data set table named in "Origin"; all data sets downloaded from census.data.gov and joined to TIGER Census block group features. There are 775 Census block groups within or intersecting the Sierra Nevada RRK region boundary.

Data Source: U.S. Department of Commerce, Census Bureau, 2020 Decennial Census Redistricting File (PL 94-171).

Racial identity data are reported in Table P1 of the PL 94-171 release. Population counts were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units above)

File Name: MultiRaceNotAmerInd_2020.tif

Low Income Population Concentration

Tier: 2

Data Vintage: 2020

Metric Definition and Relevance: Relative concentration of the estimated number of people in the Sierra Nevada region that live in a household defined as "low income." There are multiple ways to define low income. These data apply the most common standard: low income population consists of all members of households that collectively have income less than twice the federal poverty threshold that applies to their household type. Household type refers to the household's resident composition: the number of independent adults plus dependents that can be of any age, from children to elderly. For example, a household with four people – one working adult parent and three dependent children – has a different poverty threshold than a household comprised of four unrelated independent adults.

Due to high estimate uncertainty for many block group estimates of the number of people living in low income households, some records cannot be reliably assigned a class and class code comparable to those assigned to race/ethnicity data from the decennial Census.

“Relative concentration” is a measure that compares the proportion of population within each Census block group data unit to the proportion of all people that live within the 775 block groups in the Sierra Nevada RRK region. See the “Data Units” description below for how these relative concentrations are broken into categories in this “low income” metric.

Data Resolution: 30m Raster

Data Units: Categorical

- Class Code 0: *Zero or nearly zero*. The variable is absent (observed value = 0) or is very low; the local proportion of the subject population variable is 10% or less than the same proportion in the Sierra Nevada region population in total

- Class Code 1: *Low*. The subject population concentration is low; the local proportion of the subject population variable is between roughly 10% and 50% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 2: *Somewhat low*. The subject population concentration is somewhat low; the local proportion of the subject population variable is between roughly 50% and 85% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 3: *Proportionate.* The subject population concentration is roughly proportionate to the corresponding proportion in the Sierra Nevada region population in total - from about 85% to 115% of the regional proportion

- Class Code 4: *Somewhat high.* The subject population concentration is somewhat high; the local proportion of the subject population variable is between roughly 115% and 150% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 5: *High.* The subject population concentration is high; the local proportion of the subject population variable is between roughly 150% and 200% of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 6: *Very high.* The subject population concentration is very high; the local proportion of the subject population variable roughly 2 to 3 times that of the corresponding proportion in the Sierra Nevada region population in total

- Class Code 7: *Extremely high.* The subject population concentration is very extremely high; the local proportion of the subject population variable is at least 3 times that of the corresponding proportion in the Sierra Nevada region population in total (the upper limit is determined by natural breaks if exceptional outliers are present, but is typically over 6 times (600%)

- Class Code 9: *Unclassifiable.* The 90% confidence interval for the estimate is wide enough to cause the values to span four or more classes. In these cases, it is impossible to say with any reasonable certainty whether the concentration is "low" or "high."

Creation Method: Data are reported in Census block groups. Standard block groups are clusters of Census blocks within the same census tract that have the same first digit of their 4-character census block number (e.g., Blocks

3001, 3002, 3003 to 3999 in census tract 1210.02 belong to block group 3). Block groups delineated for the 2020 Census generally contain 600 to 3,000 people.

Census blocks are statistical areas bounded on all sides by visible features (e.g., streets, roads, streams, and railroad tracks), and by non-visible boundaries (e.g., city, town, township, county limits, and short line-of-sight extensions of streets and roads). Census blocks in suburban and rural areas may be large, irregular, and bounded by a variety of features (e.g., roads, streams, and/or transmission line rights-of-way). In remote areas, census blocks may encompass hundreds of square miles. Census blocks cover all territory in the United States, Puerto Rico, and the Island areas. Blocks do not cross the boundaries of any entity for which the Census Bureau tabulates data. See note 1.

Data describing concentrations of population characteristics that are potentially related to environmental justice issues were provided to CWI through a collaboration with the USDA Forest Service, Geospatial Technology and Applications Center. The concentration methodology was created by GTAC for social science analysis applications within the Forest Service; it is based on research published in 2018 and 2020 (See Note 2). Data were compiled and prepared for incorporating in the regional resource kits by Mark Adams, Geographer, USFS-GTAC. For more information, contact: mark.adams1@usda.gov.

Notes: The pixels attributed with a categorical data unit describing the relative concentration of LOW_INCOME population are derived from a vector polygon feature that has been modified as follows: Census block groups from the Census Bureau's TIGER/Line geodatabase features for 2021 are selected based on their spatial intersection with the Sierra Nevada RRK boundary. The resulting 775 block group features are modified by first erasing from the feature the area of all constituent Census blocks which have neither housing nor population recorded in the PL-94171 Redistricting dataset for 2020. In a second step, areas of federal and state public lands on which housing by definition is not located are erased from the interim feature. The result is a block group feature that depicts to the maximum practicable extent the areas within the block group where people that are represented by the Census Bureau's Census count could actually be residing. It is this modified block group feature that has been rasterized to match the 30m pixel grid that all biophysical datasets are reported in.

References for the concentration levels analysis:

- Adams, Mark D. O. and S. Charnley. 2020. The Environmental Justice Implications of Managing Hazardous Fuels on Federal Forest Lands, Annals of the American Association of Geographers, 110:6, 1907-1935, DOI: 10.1080/24694452.2020.1727307

- Adams, Mark D. O. and S. Charnley. 2018. Environmental justice and U.S. Forest Service hazardous fuels reduction: A spatial method for impact assessment of federal resource management actions. https://doi.org/10.1016/j.apgeog.2017.12.014

Data Source: U.S. Department of Commerce, Census Bureau, 2020 American Community Survey 5-Year Survey Estimates.

Data estimating household income as a percent of the applicable federal poverty threshold are reported in Table C17002 of the 2020 ACS 5-year data. Estimates of population living in low income households were obtained via the Data.Census.Gov web portal and joined to the Census Bureau's TIGER/line feature classes for block groups (see reporting units below). Table C17002 provides estimates and error margins for total population living in households with income, and population by ratio of income to applicable poverty: 50% of poverty, 50-99%, etc.

Additional calculations are performed to generate an estimate for all people in households with income less than 200% of applicable poverty.

FMI: https://www.census.gov/newsroom/press-releases/2022/acs-5-year-estimates.html

File Name: LowIncome_2020.tif

Poverty Percentile

Tier: 1

Data Vintage: 10/2021

Metric Definition and Relevance: Percent of population living below two times the federal poverty level. The U.S. Census Bureau determines the federal poverty level each year. The poverty level is based on the size of the household and the age of family members. If a person or family's total income before taxes is less than the poverty level, the person or family are considered in poverty. Many studies have found that people living in poverty are more likely than others to become ill from pollution.

Data Resolution: 30m Raster

Data Units: percentile

Creation Method: CalEnviroScreen, Version 4.0, is a science-based method for identifying impacted communities by taking into consideration pollution exposure and its effects, as well as health and socioeconomic status, at the census-tract level. CalEnviroScreen 4.0 uses the census tract as the unit of analysis. Census tract boundaries are available from the Census Bureau. CalEnviroScreen uses the Bureau's 2010 boundaries. New boundaries will be drawn by the Census Bureau as part of the 2020 Census but will not be available until after 2022. OEHHA will address updates to census tract geography in CalEnviroScreen at that time. There are approximately 8,000 census tracts in California, representing a relatively fine scale of analysis. Census tracts are made up of multiple census blocks, which are the smallest geographic unit for which population data are available. Some census blocks have no people residing in them (unpopulated blocks).

The poverty percentile is derived from

- The 2015-2019 American Community Survey, a dataset containing the number of individuals below 200 percent of the federal poverty level was downloaded by census tracts for the state of California.
- The number of individuals below 200% of the poverty level was divided by the total population for whom poverty status was determined.
- Unlike the US Census, ACS estimates come from a sample of the population and may be unreliable if they are based on a small sample or population size. The standard error (SE) and relative standard error (RSE) were used to evaluate the reliability of each estimate.
- The SE was calculated for each census tract using the formula for approximating the SE of proportions provided by the ACS (American Community Survey Office, 2013, pg. 13, equation 4). CalEnviroScreen 4.0 189 When this approximation could not be used, the formula for approximating the SE of ratios (equation 3) was used instead.
- The RSE is calculated by dividing a tract's SE by its estimate of the percentage of the population living below twice the federal poverty level, and taking the absolute value of the result.
- Census tract estimates that met either of the following criteria were considered reliable and included in the analysis:
    - RSE less than 50 (meaning the SE was less than half of the estimate) OR

- SE was less than the mean SE of all California census tract estimates for poverty.

- Census tracts with unreliable estimates received no score for the indicator (null). The indicator was not factored into that tract's overall CalEnviroScreen score.
- Census tracts that met the inclusion criteria were sorted and assigned percentiles based on their position in the distribution.

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0, [CalEnviroScreen 4.0 | OEHHA]

File Name: Poverty_Pctl_202110.tif

Housing Burden Percentile

Tier: 1

Data Vintage: 2021

Metric Definition and Relevance: Housing-Burdened Low-Income Households. Percent of households in a census tract that are both low income (making less than 80% of the HUD Area Median Family Income) and severely burdened by housing costs (paying greater than 50% of their income to housing costs). (5-year estimates, 2013-2017).

The cost and availability of housing is an important determinant of well-being. Households with lower incomes may spend a larger proportion of their income on housing. The inability of households to afford necessary non-housing goods after paying for shelter is known as housing-induced poverty. California has very high housing costs relative to much of the country, making it difficult for many to afford adequate housing. Within California, the cost of living varies significantly and is largely dependent on housing cost, availability, and demand.

Areas where low-income households may be stressed by high housing costs can be identified through the Housing and Urban Development (HUD) Comprehensive Housing Affordability Strategy (CHAS) data. We measure households earning less than 80% of HUD Area Median Family Income by county and paying greater than 50% of their income to housing costs. The indicator takes into account the regional cost of living for both homeowners and renters, and factors in the cost of utilities. CHAS data are calculated from US Census Bureau's American Community Survey (ACS).

Data Resolution: 30m raster

Data Units: Percent

Creation Method: CalEnviroScreen, Version 4.0, is a science-based method for identifying impacted communities by taking into consideration pollution exposure and its effects, as well as health and socioeconomic status, at the census-tract level. CalEnviroScreen 4.0 uses the census tract as the unit of analysis. Census tract boundaries are available from the Census Bureau. CalEnviroScreen uses the Bureau's 2010 boundaries. New boundaries will be drawn by the Census Bureau as part of the 2020 Census but will not be available until 2022. OEHHA will address updates to census tract geography in CalEnviroScreen at that time. There are approximately 8,000 census tracts in California, representing a relatively fine scale of analysis. Census tracts are made up of multiple census blocks, which are the smallest geographic unit for which population data are available. Some census blocks have no people residing in them (unpopulated blocks).

The CalEnviroScreen model is based on the CalEPA working definition in that:

- The model is place-based and provides information for the entire State of California on a geographic basis. The geographic scale selected is intended to be useful for a wide range of decisions.

- The model is made up of multiple components cited in the above definition as contributors to cumulative impacts.
- The model includes two components representing Pollution Burden – Exposures and Environmental Effects
- The model includes two components representing Population Characteristics – Sensitive Populations (e.g., in terms of health status and age) and Socioeconomic Factors.

The American Community Survey (ACS) is an ongoing survey of the US population conducted by the US Census Bureau and has replaced the long form of the decennial census. Unlike the decennial census, which attempts to survey the entire population and collects a limited amount of information, the ACS releases results annually based on a sub-sample of the population and includes more detailed information on socioeconomic factors. Multiple years of data are pooled together to provide more reliable estimates for geographic areas with small population sizes. Each year, the HUD receives custom tabulations of ACS data from the US Census Bureau. These data, known as the "CHAS" data (Comprehensive Housing Affordability Strategy), demonstrate the extent of housing problems and housing needs, particularly for low-income households. The most recent results available at the census tract scale are the 5-year estimates for 2013-2017. The data are available from the HUD user website (see page 174 in the document link below:

https://oehha.ca.gov/media/downloads/calenviroscreen/report/calenviroscreen40reportf2021.pdf

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0

File Name: HousingBurdenPctl_2021_30m.tif

Unemployment Percentile

Tier: 1

Data Vintage: 2021

Metric Definition and Relevance: Percentage of the population over the age of 16 that is unemployed and eligible for the labor force. Excludes retirees, students, homemakers, institutionalized persons except prisoners, those not looking for work, and military personnel on active duty (5-year estimate, 2015-2019).

Because low socioeconomic status often goes hand-in-hand with high unemployment, the rate of unemployment is a factor commonly used in describing disadvantaged communities. On an individual level, unemployment is a source of stress, which is implicated in poor health reported by residents of such communities. Lack of employment and resulting low income often constrain people to live in neighborhoods with higher levels of pollution and environmental degradation.

Data Resolution: 30m raster

Data Units: Percent

Creation Method: CalEnviroScreen, Version 4.0, is a science-based method for identifying impacted communities by taking into consideration pollution exposure and its effects, as well as health and socioeconomic status, at the census-tract level. CalEnviroScreen 4.0 uses the census tract as the unit of analysis. Census tract boundaries are available from the Census Bureau. CalEnviroScreen uses the Bureau’s 2010 boundaries. New boundaries will be drawn by the Census Bureau as part of the 2020 Census but will not be available until 2022. OEHHA will address updates to census tract geography in CalEnviroScreen at that time. There are approximately 8,000 census tracts in California, representing a relatively fine scale of analysis. Census tracts are made up of multiple census blocks, which are the smallest geographic unit for which population data are available. Some census blocks have no people residing in them (unpopulated blocks).

The CalEnviroScreen model is based on the CalEPA working definition in that:

- The model is place-based and provides information for the entire State of California on a geographic basis. The geographic scale selected is intended to be useful for a wide range of decisions.
- The model is made up of multiple components cited in the above definition as contributors to cumulative impacts.
- The model includes two components representing Pollution Burden – Exposures and Environmental Effects
- The model includes two components representing Population Characteristics – Sensitive Populations (e.g., in terms of health status and age) and Socioeconomic Factors.

The American Community Survey (ACS) is an ongoing survey of the US population conducted by the US Census Bureau. Unlike the decennial census, which attempts to survey the entire population and collects a limited amount of information, the ACS releases results annually based on a sub-sample of the population and includes more detailed information on socioeconomic factors such as unemployment. Multiple years of data are pooled together to provide more reliable estimates for geographic areas with small population sizes. The most recent results available at the census tract level are the 5-year estimates for 2015-2019. The data are made available using the U.S. Census data download website.

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0

File Name: UnemploymentPctl_2021_30m.tif

Water Security

Forests serve as natural water collection, storage, filtration, and delivery systems as water flows from forests into rivers providing critical aquatic and wetland habitat, while also supplying water for drinking and agriculture. From a more mechanistic perspective, the energy and water balance of forest ecosystems are fundamentally linked. Water is essential to photosynthesis and the latent energy exchange of transpiration is a major driver of water loss. In short, the fate of forests directly influences the quantity and quality of California's freshwater supply.

DESIRED OUTCOME: Watersheds provide a reliable supply of clean water despite wide swings in annual precipitation, droughts, flooding, and wildfire.

Quantity

Understanding the interaction between water supply and ecosystem demand informs both the extent of moisture stress and the amount of water available for storage.

Actual Evapotranspiration to Precipitation Fraction During Drought

Tier: 1

Data Vintage: 09/2021

Metric Definition and Relevance: Plants respond to conditions in their immediate vicinity. Thus, to understand the vegetative moisture stress during drought, it is important to measure the local moisture balance. The actual evapotranspiration fraction (AETF) provides such a measure. Specifically, it indicates whether a location is expected to experience local drying during a drought, or whether the location receives sufficient precipitation that it will remain moist even during an extended drought. An extended drought is defined by a 48-month period where the Standardized Precipitation Index (SPI, NCAR 2022) is two standard deviations below the long-term mean (SPI-48 = negative 2). Such a drought is expected approximately once every 50 years in the Northern California Region.The AETF ranges from 0 to > 1; a low value indicates a wetter location during drought and a high value indicates a drier location. Locations <1 would be expected to generate runoff, even during a significant drought (SPI-48 drought = negative 2.0), and would be expected to continue generating runoff. Locations > 1 would be expected to desiccate the soil during drought, with negligible runoff, and increasing vegetation drought stress. AET/P does not account for lateral water inflow, either as runoff or irrigation.

Data Resolution: 30m Raster

Data Units: Dimensionless fraction (AET in mm/P in mm).

Creation Method: Calculated as the ratio of actual evapotranspiration (AET) during 2021 Water Year (WY) and precipitation that would be expected for each pixel under a significant drought (SPI-48 drought = negative 2.0). AET is calculated based on Landsat observations and eddy covariance, along with information on local monthly irradiance that accounts for Top of Atmosphere and topographic effects. The AET calculated for 2021 is then divided by the precipitation that would be expected for each pixel under a significant drought (SPI-48 drought = negative 2.0). This quantity of precipitation is calculated for each pixel based on local, down-scaled PRISM data for 1991-2020. This fraction provides a measure of the local water balance during drought, with the higher values indicating a drier location. See https://doi.org/10.1029/2012JG002027 and https://doi.org/10.1073/pnas.1319316111 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: WaterFlux_AETFrac_SPI-2_202109.tif

Precipitation Minus Actual Evapotranspiration during average conditions

Tier: 1

Data Vintage: 09/2021

Metric Definition and Relevance: Runoff is a measure of the water available for storage. It is determined by both the water supply and the demand of the existing vegetation. Annual mean runoff measures the “average” vegetative demand and thus provides a comparative index on the potential available runoff. Specifically, Annual Mean Runoff is the expected surplus water that would discharge to surface or groundwater flows during a series of years with average precipitation. Larger values indicate more runoff under mean conditions.

Data Resolution: 30m Raster

Data Units: mm/y

Creation Method: The Center for Ecosystem Climate Solutions at UC Irvine (CECS) is working with the State and Federal governments in developing scientifically rigorous, stakeholder-informed methods that have produced tailored, integrated data for land management decision makers. The CECS DataEngine model tracks monthly water balance from 1986 to 2021. The Annual Mean Runoff layer is calculated using this CECS DataEngine model logic forced with a series of 4 years that each received precipitation according to the timing and magnitude of the 30-year climate Normal Precipitation (SPI = 0 by definition).

The model water inputs are determined from downscaled PRISM gridded datasets (https://prism.oregonstate.edu/). In the case of the Annual Mean Runoff, this reflects the monthly 30 year Normal for each pixel calculated for 1991-2020. Actual evapotranspiration (AET) is calculated from Landsat observations and eddy covariance during 2021, along with information on local monthly irradiance that accounts for Top of Atmosphere (TOA) and topographic effects, as well as monthly temperature and drought stress. Precipitation Minus Actual Evapotranspiration is calculated as the difference; it provides an excellent measure of the long-term runoff from upland pixels. Areas with a higher P-ET produce greater runoff, and areas with a low P-ET tend to produce little or no runoff during average or dry years. See https://doi.org/10.1029/2012JG002027 and https://doi.org/10.1073/pnas.1319316111 for further information.

Data Source: CECS; https://california-ecosystem-climate.solutions/

File Name: WaterFlux_Runoff_SPI0_202109.tif

Groundwater Basin Boundaries

Tier: 3

Data Vintage: 02/2022

Metric Definition and Relevance: This dataset shows the boundaries of groundwater basins and subbasins as defined by the California Department of Water Resources as last modified by the Basin Boundary Emergency Regulation adopted on October 21, 2015 and subsequent modifications requested through the Basin Boundary Modification Request Process.

Data Resolution: 30m raster

Data Units: Binary

Creation Method: Groundwater basins are represented as polygon features and designated on the basis of geological and hydrological conditions - usually the occurrence of alluvial or unconsolidated deposits. When practical, large basins are also subdivided by political boundaries, as in the Central Valley. Basins are named and numbered per the convention of the Department of Water Resources.

These boundaries have been converted from a polygon vector to a 30 meter raster by the RRK team and clipped to the Sierra Nevada RRK.

Data Source: California Department of Water Resources

https://gis.water.ca.gov/arcgis/rest/services/Geoscientific/i08_B118_CA_GroundwaterBasins/FeatureServer

File Name: i08_B118_CA_GroundwaterBasins.tif

Wetland Integrity

Wetlands provide critical habitat, store carbon, enhance water quality, control erosion, filter and retain nutrient pollution, and provide spaces for recreation. They are local and regional centers of biodiversity, and support species found nowhere else across western landscapes. Functional wetland ecosystems will serve increasingly important roles in buffering impacts from extreme climate events, and upland disturbances such as flooding and erosion. Meadow and riparian ecosystems provide ecosystem services and are key linkages between upland and aquatic systems in forested landscapes.

DESIRED OUTCOME: Wetland ecosystems are biologically intact, provide multiple ecosystem services, and meadow and riparian ecosystems provide key linkages between upland and aquatic systems in forested landscapes.

Hydrologic Function

Hydrologic systems in the Sierra Nevada function through a complex interaction of topographic patterns, interannual variability of precipitation, and heterogeneous mosaics of vegetation to yield water and maintain valuable wetland habitats. Land management can have profound impacts on the hydrologic function of mountainous landscapes.

Meadow Sensitivity Index

Tier: 2

Data Vintage: 2019

Metric Definition and Relevance: Sensitivity is a measure of the slope of the relationship between April 1st Snowpack and September vegetation wetness (Normalized Difference Water Index; NDWI). Data is based on percentile rank for the study region.

The purpose of this dataset is to be used in conjunction with the decision framework: Gross, S., M. McClure, C. Albano, and B. Estes. 2019. *A spatially explicit meadow vulnerability decision framework to prioritize meadows for restoration and conservation in the context of climate change. Version 1*. The decision framework and this dataset can aid in the prioritization of meadow conservation and restoration in the context of other priorities in the Sierra Nevada and Cascade ranges in California.

Data Resolution: 30m raster

Data Units: Relative index

Creation Method: This dataset was developed based on Albano et. al. 2019 and is a spatially explicit vulnerability assessment for the meadows in the Sierra Nevada ecoregion based on water availability and stress. By joining the climate vulnerability point layer on ID to the Sierra Nevada Multi-source Meadow Polygon Compilation layer, the meadow polygons that had values for the Sensitivity Index (SensNDWI) were selected and converted to raster.

Data Source: Center for Watershed Sciences, UC Davis – see Meadows

File Name: Meadow_SensNDWI_2019_30m.tif

Composition

Wetland composition pertains to the array of different wetland types, their relative abundance, the uniqueness of their co-occurrence and composition, and their integrity in a given location and area within and across landscapes. Wetland ecosystems include all lentic (e.g. lakes, ponds, bogs, fens) and lotic (e.g., rivers, streams, springs, seeps) aquatic ecosystems, as well as associated vegetated wetlands such as wet meadows and riparian vegetation.

Aquatic Species Richness

Tier: 1

Data Vintage: 2019

Metric Definition and Relevance: Aquatic native species richness is a measure of species biodiversity, and is one measurement used to describe the distribution of overall species biodiversity in California for the California Department of Fish and Wildlife (CDFW) Areas of Conservation Emphasis Project (ACE). Native species richness represents a count of the total number of native aquatic species potentially present in each watershed based on species range and distribution information. The data can be used to view patterns of species diversity, and to identify areas of highest native richness across the state. The species counts consist of four taxonomic groups – fish, aquatic invertebrates, aquatic amphibians, and aquatic reptiles.

Data Resolution: 30m raster

Data Units: Count

Creation Method: For more information, see the Aquatic Native Species Richness Factsheet (2018) at https://nrm.dfg.ca.gov/Filehandler.aashx?DocumentID=150852

The California Department of Fish and Wildlife (CDFW) Areas of Conservation Emphasis (ACE) is a compilation and analysis of the best-available statewide spatial information in California on biodiversity, rarity and endemism, harvested species, significant habitats, connectivity and wildlife movement, climate vulnerability, climate refugia, and other relevant data (e.g., other conservation priorities such as those identified in the State Wildlife Action Plan (SWAP), stressors, land ownership). ACE addresses both terrestrial and aquatic data.

Data Source:

- Aquatic Native Species Richness Summary, Areas of Conservation Emphasis (ACE), version 3.0, California Department of Fish and Wildlife (CDFW)
- ACE data base

File Name: aquatic_species_richness.tif

Wetland Diversity

Tier: 1

Data Vintage: 06/2018

Metric Definition and Relevance: This data set represents the extent, approximate location, and type of wetlands and deepwater habitats in California. These data delineate the areal extent of wetlands and surface waters as defined by Cowardin et al. (1979).

Data Resolution: 30m raster

Data Units: Thematic

Creation Method: Downloaded from the National Wetlands Inventory (NWI), polygon converted to 30 meter raster. For more information see https://www.fws.gov/program/national-wetlands-inventory.

Definition of values:

- Lake = Lake or reservoir basin. Lacustrine wetland and deepwater (L).
- Freshwater Emergent Wetland = Herbaceous marsh, fen, swale and wet meadow. Palustrine emergent (PEM).
- Estuarine and Marine Wetland = Vegetated and non-vegetated brackish and saltwater marsh, shrubs, beach, bar, shoal or flat. Estuarine intertidal and Marine intertidal wetland (E2, M2).

- Other = Farmed wetland, saline seep and other miscellaneous wetland. Palustrine wetland (Misc. types, PUS, Pf..)
- Freshwater Pond = Pond. Palustrine unconsolidated bottom, Palustrine aquatic bed (PUB, PAB).
- Estuarine and Marine Deepwater = Open water estuary, bay, sound, open ocean. Estuarine and Marine subtidal water (E1, M1).
- Riverine = River or stream channel. Riverine wetland and deepwater (R).
- Freshwater Forested/Shrub Wetland = Forested swamp or wetland shrub bog or wetland. Palustrine forested and/or Palustrine shrub (PFO, PSS).

Data Source: The National Wetlands Inventory, US Fish & Wildlife Service (USFWS)

File Name: NWI_WetlandsType_2018_30m.tif

Riparian Habitat

Tier: 1

Data vintage: 04/2019

Metric Definition and Relevance: These data depict 10-meter raster riparian areas for 50-year flood heights for California in 2019.

Data Resolution: 10m Raster

Data Units: binary

Creation Method: Fifty-year flood heights were estimated using U.S. Geological Survey (USGS) stream gage information. NHDPlus version 2.1 was used as the hydrologic framework to delineate riparian areas. The U.S. Fish and Wildlife Service's National Wetland Inventory and USGS 10-meter digital elevation models were also used in processing these data. See https://doi.org/10.2737/RDS-2019-0030

Credits: Sinan Abood, Ph.D. GISP; Research Scientist, Forest Service Washington Office (WO) – Biological & Physical Resources (BPR)

Data Source: USDA Forest Service

File Name: RiparianAreas10m_2019.tif

Operational Data Layers

In addition to the metric data layers assembled for this RRK project, a set of "operational" GIS data layers have been assembled to support use of the metrics. These data provide land use context (e.g. ownership, land use designations, background ecological information (e.g. climate refugia, stream locations, climate classes), infrastructure (roads, operational constraints, powerline corridors), and Forest Service policy information (spotted owl PACs, critical habitat maps for listed species, wilderness/roadless/wild and scenic rivers). These data are provided to assist managers in putting proposed treatments into context for what is feasible and what might constrain project planning.

Some data layers provided within this designation of operational data are in their native projection and format with any embedded metadata maintained.

Administrative

Urban-Agriculture Land Use

Definition and Relevance: This dataset covers the urban and agricultural landscape for all forms of urban and agricultural land use in California. It was created using a combination of best available land cover data from multiple sources (see below). These data are used as a mask for selected metrics in the RRK project where inclusion of urban and agricultural cover potentially creates confusion in calculations of the metric.

Data Vintage: 06/2020

Data Resolution: Raster, 30m

Data Units: Thematic

Creation Method:

1. Farmland Mapping and Monitoring Program (FMMP) land-use data from 2018 was converted to 30m raster as the base input, using the values from the Type field of:
   - Farmland of Statewide Importance
   - Unique Farmland
   - Farmland of Local Importance
   - Urban and Built-Up Land
   - Rural Residential Land
   - Confined Animal Agriculture

2. Secondly, to bring more current data in, LANDFIRE 2020 Existing Vegetation Type (EVT) from 2020 was converted to 30m raster, using the values from EVT group name of:
   - Developed-Low Intensity
   - Developed-Medium Intensity
   - Developed-High Intensity
   - Agriculture-Cultivated Crops and Irrigated Agriculture
3. Lastly, Building Footprints - Bing Maps (microsoft.com) polygons were converted to 30m raster and added to the stack to include the most recent urban footprints.

Data Source:

Farmland Mapping and Monitoring Program (FMMP)
LANDFIRE: Existing Vegetation Type, U.S. Department of Agriculture and U.S. Department of the Interior
MS Building Footprints

File Name: UrbanAgLanduse_RRK_2020.tif

Building Structure Density

Definition and Relevance: A raster dataset containing building footprints of California. The vintage of the footprints depends on the vintage of the underlying imagery. Bing Imagery is a composite of multiple sources with different capture dates.

Data Vintage: 2012-2020.

Data Resolution: Raster, 10m

Data Units: binary

Creation Method: Vector spatial data called US Building Footprints contained in a Microsoft dataset (available at https://github.com/microsoft/USBuildingFootprints) downloaded, clipped to California and converted to a 10m raster. For more information visit: Building Footprints - Bing Maps (microsoft.com)

Data Source: MS Building Footprints

File Name: CA_bldgFootprints_10m.tif

Biomass Power Plants and Sawmills

Definition and Relevance: This layer displays data for currently operational biomass power plants and sawmill within California.

Data Vintage: 06/2022

Data Resolution: Vector, points

Data Units: Attribute definitions can be accessed here:
https://docs.google.com/spreadsheets/d/e/2PACX-1vS8af0NSblXJU-TECBSvCHprNrCxR87a30BBMpZbpp7yxrWTerQe4uRcJXc5_-51TyisQVI1nr2JdnX/pubhtml?gid=764308543&single=true

Creation Method: Tabular data were downloaded from the University of California Cooperative Extension Wood Facilities Database and x, y (longitude, latitude) coordinates were converted to points.

Data Source: University of California Cooperative Extension Wood Facilities Database

https://ucanr.edu/sites/WoodyBiomass/California_Biomass_Power_Plants

File Name: BiomassPowerPlants_CA_2023.shp, Sawmills_CA_2023.shp

---

High-Use Recreation Areas

Data Vintage: 2022

Definition and Relevance: A recreation site is a discrete area on a Forest that provides recreation opportunities, receives recreational use, and requires a management investment to operate and/or maintain to standard under the direction of an administrative unit in the National Forest System. Recreation sites range in development from relatively undeveloped areas, with little to no improvements (Development Scale 0 and 1), to concentrations of facilities and services evidencing a range of amenities and investment (Development Scale 2 through 5).

Recreation opportunities are point locations of recreational site activities available to visitors and populates the Forest Service websites (https://www.fs.usda.gov/), and the interactive visitor map (https://www.fs.usda.gov/ivm/).

Data Resolution: Vector, Points and Lines

Data Units: Tabular attributes

Creation Method: see Metadata

Data Source: USFS Enterprise Data Warehouse (EDW)

File Name: RECAREAACTIVITIES_V_2023.shp

Land Designations

Data Vintage: 2022

Definition and Relevance: Wilderness, Roadless, Wild and Scenic River

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method: Data layers pulled from the Enterprise Data Warehouse for land designations:

- *Wilderness* – area designated as a National Wilderness in the National Wilderness Preservation System
- *Inventoried Roadless Areas* – the 2001 Roadless Rule establishes prohibitions on road construction, road reconstruction, and timber harvesting on inventoried roadless areas on National Forest System lands by the following classifications:
  - 1B = Inventoried Roadless Areas where road construction and reconstruction is prohibited
  - 1B-1 = Inventoried Roadless Areas that are recommended for wilderness designation in the forest plan and where road construction and reconstruction is prohibited
  - 1C = Inventoried Roadless Areas where road construction and reconstruction is not prohibited
- *Wild and Scenic Rivers* – area designated as a National Wild, Scenic, or Recreational River within the National Wild and Scenic River System. The designations and definitions are:
  - Wild (W) – Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.
  - Scenic (S) – Those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.
  - Recreational (R) – Those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.

Data Source: USFS Enterprise Data Warehouse (EDW)

File Name: Wilderness_2023.shp; WildScenicRiver_2023.shp; RoadlessArea_2001.shp

Wilderness - Protected Area Database 3.0

Definition and Relevance: The PAD-US geodatabase was originally developed to organize and assess the management status (i.e. apply 'GAP Status Code') of elements of biodiversity protection by identifying species and plant communities not adequately represented in existing conservation lands (https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap). In cooperation with the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), PAD-US also supports global conservation analyses to inform policy decisions (https://www.protectedplanet.net/country/USA , https://www.protectedplanet.net/en/resources/global-reports). The dataset is robust and has been expanded in recent years with major additions of local parks data to PAD-US 2.1, to support the recreation, natural resource management, wildfire planning, emergency management, transportation, research, and public health communities. New applications of the data are frequently discovered. Multiple attributes and a flexible database structure provide context for data to be used at local, regional, state, national, and international scales. See https://www.usgs.gov/gapanalysis/PAD-US-resources for more information.

Includes wilderness on ALL federal lands within California.

Data Vintage: 01/2022

Data Resolution: File Geodatabase Polygon Feature Class

Data Units: Tabular attributes

Creation Method: Polygons with [Designation Type] = 'Wilderness' extracted from the PADUS3_0_State_CA_GDB feature class for use in the RRK project. Polygons projected to California Teale Albers projection and 'exploded' into single part features.

Data Source: U.S. Geological Survey (USGS)

File Name: PAD3_0_Wilderness.gdb/PAD_Wilderness3_0_2022_CA_sPart

---

Ownership

Definition and Relevance: Ownership is a commonly used base layer used in a wide range of business functions and these data are intended to provide a depiction of the land ownership within the RRK project area. Two different data layers are provided, from different sources.

Data Vintage: FS_BasicOwnership: 01/2023, ownership: 05/2022

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method:

- *FS_BasicOwnership_2022.shp* – an area depicted as surface ownership parcels dissolved on the same ownership classification administered by the USDA Forest Service (USFS).
- *ownership22_1* – California Multi-Source Land Ownership, includes lands owned by each federal agency (including USFS), state agency, local government entities, conservation organizations, and special districts. It does not include lands of private ownership.

Data Source: USDA Forest Service, CAL FIRE

File Name: FS_BasicOwnership_2023.shp; ownership22_1.shp

Roads

Definition and Relevance: This California statewide dataset was downloaded from Geofabrik's free download server for California. This server has data extracts from the OpenStreetMap project which are normally updated every day.

Data Vintage: 09/2022

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method: To simplify the layer, major roads were exported with the following selection of the attribute "fclass":

- 5111 = motorway
- 5112 = trunk
- 5113 = primary
- 5114 = secondary
- 5121 = unclassified
- 5122 = residential
- 5123 = living street

Data Source: Open Street Map roads based on Tiger Lines (OSM)

File Name: OSM_majorRoads_CA_2022.shp

Low Voltage Transmission Lines

Definition and Relevance: This electric transmission line California statewide dataset was downloaded from PG&E (Pacific Gas & Electric) and was subsetted to include only lines less than or equal to 115 kV (kilovolts). This subset was chosen from the original dataset for use in planning because it has been determined (via inspections of PG&E database of fires caused by power lines from 2020-2022) that virtually every fire caused by power lines was from a distribution lines less than 115 kv. Most wildfires caused by power lines are from distribution lines less than 44kv. Thus this database provides information on where those power lines are and can be used to compare with locations that have potential for high severity wildfire.

Data Vintage: 2023

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method: PG&E's Integration Capacity Analysis (ICA) map is designed to help contractors and developers find information on potential project sites for distributed energy resources (DERs). ICA is a complex modeling study that uses detailed information about the electric distribution system, which includes items such as physical infrastructure, load performance, and existing and queued generators. The analysis simulates the ability of individual distribution line sections to accommodate additional DERs without potentially causing issues that would impact customer reliability and power quality. Potential issues could result in distribution line upgrade requirements that would impact cost and/or timeline for DER interconnections.

Transmission lines:

- Carry electricity across the state
- Transport bulk electricity at high voltages ranging from 60 kV-500 kV
- Are usually supported on tall metal towers, but sometimes on wooden poles
- Have different vegetation standards than distribution lines due to the high voltages they carry

- Are managed using the utility industry's best-management practice of Wire Zone Border Zone
- Require only low-growing vegetation underneath—typically nothing taller than 10 feet at maturity

https://www.pge.com/en_US/safety/yard-safety/powerlines-and-trees/transmission-vs-distribution-power-lines.page

Data Source: PG&E
PG&E Integration Capacity Analysis and Distribution Investment Deferral Framework maps (pge.com)

File Name: TransmissionLines_upTo_115kV.shp

Distribution Lines

Definition and Relevance: This electric distribution line California statewide dataset was downloaded from PG&E (Pacific Gas & Electric). This 'FeederDetail' dataset carries voltage under the 'Nominal_Voltage' attribute for the distribution system, all under 44kV. These distribution lines often can cross wildlands and through vegetated areas and are typically the most likely to be related to a wildfire.

Data Vintage: 2023

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method: PG&E's Integration Capacity Analysis (ICA) map is designed to help contractors and developers find information on potential project sites for distributed energy resources (DERs). ICA is a complex modeling study that uses detailed information about the electric distribution system, which includes items such as physical infrastructure, load performance, and existing and queued generators. The analysis simulates the ability of individual distribution line sections to accommodate additional DERs without potentially causing issues that would impact customer reliability and power quality. Potential issues could result in distribution line upgrade requirements that would impact cost and/or timeline for DER interconnections.

Distribution lines:

- Deliver electricity to neighborhoods and communities over a shorter distance than transmission lines
- Are generally supported by wooden poles and not as high as transmission lines
- Are the final stage of electricity delivery to homes and businesses
- Carry lower voltage electricity that is still powerful enough to cause injury or death
- Trees growing near these lines may be managed with directional pruning, but removal is often best.

https://www.pge.com/en_US/safety/yard-safety/powerlines-and-trees/transmission-vs-distribution-power-lines.page

Data Source: PG&E
PG&E Integration Capacity Analysis and Distribution Investment Deferral Framework maps (pge.com)

File Name: FeederDetail.shp

FOREST TYPE

Data Vintage: 2021

Definition and Relevance: Managers work with forest types for a variety of purposes and knowing the major forest type of a target location helps to assess the best suited treatment for the site.

Data Resolution: 30m Raster

Data Units: FIA Forest Type Code

Creation Method: The F3 model relies on FVS to classify an FIA plot to a forest or vegetation type. The assigned forest or vegetation type is then imputed across the project area. Appendix B from the Essential FVS User's guide provides a complete list of FIA forest types (https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf). The following is the list of FIA Forest Types within the SNV RRK project area:

FIA Code	Forest Type
183	Western Juniper
184	Juniper Woodland
185	Pinyon Juniper Woodland
221	Ponderosa Pine
222	Incense-cedar
224	Sugar Pine
241	Western White Pine
261	White Fir
262	Red Fir
270	Mountain Hemlock
281	Lodgepole Pine
342	Giant Sequoia
361	Knobcone Pine
365	Foxtail Pine / Bristlecone Pine
366	Limber Pine
367	Whitebark Pine
371	California Mixed Conifer
703	Cottonwood
901	Aspen
911	Red Alder
912	Bigleaf Maple
921	Gray Pine
922	California Black Oak
923	Oregon White Oak
924	Blue Oak
925	Deciduous Oak Woodland

931	Coast Live Oak
932	Canyon Live Oak / Interior Live Oak
941	Tanoak
942	California Laurel
951	Pacific Madrone
953	Mountain Brush Woodland
997	FVS Other Hardwoods
999	Non-stocked

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The resulting value was subtracted from 2019 canopy cover to give 2021 canopy cover.

$$2021\ Canopy\ Cover = 2019\ Canopy\ Cover - (2019\ Canopy\ Cover * MMI/100)$$

It should be noted that the same MMI-based adjustment was used for CPYCOVR and STANDCC (corrected for crown overlap) which are based on stockable area for all live trees. For areas where 2021 STANDCC values dropped below 10%, the forest type code was changed to 999 (non-stocked).

Data Source: F3 data outputs, Region 5, MARS Team

File Name: Total3Run_FORTYPE_NoMGT_2021_V20220512.tif

Protected Activity Centers (PAC)

Data Vintage: 2022

Definition and Relevance: The USDA Forest Service designates a 300-acre protected activity center (PAC) around each known nesting area or activity center. PACs are a USFS land allocation designed to protect and maintain high-quality nesting and roosting habitat around active sites. Territorial owls typically defend a geographic area consistently used for nesting, roosting, and foraging, containing essential habitat for survival and reproduction. The USDA Forest Service calls for an area of 1,000 acres in the central Sierra Nevada around core use areas, including the associated protected activity center, with a minimum of 400 acres of suitable habitat.

Data Resolution: ArcGIS geodatabase, Vector, polygon

Data Units: Tabular attributes

Description: The CSO PAC and the Northern goshawk's PAC is 300 acres of suitable nesting habitat in a contiguous block.

Creation Method: Downloaded from USFS NRM using the Geospatial Interface (GI)

Data Source: USFS_NRIS_FAUNA for Natural Resource Manager (NRM) Wildlife

File Name: ProtectedActivityCenters.gdb\SNV_All_PACS_20220301

Definition and Relevance: Land use data is critically important to the work of the Department of Water Resources (DWR) and other California agencies. Understanding the impacts of land use, crop location, acreage, and management practices on environmental attributes and resource management is an integral step in the ability of Groundwater Sustainability Agencies (GSAs) to produce Groundwater Sustainability Plans (GSPs) and implement projects to attain sustainability.

Data Vintage: 2021

Data Resolution: Vector, polygons

Data Units: thematic - Fields were attributed with DWR crop categories and included citrus/subtropical, deciduous fruits and nuts, field crops, grain and hay, idle, pasture, rice, truck crops, urban, vineyards, and young perennials.

Creation Method: Land IQ was contracted by DWR to develop a comprehensive and accurate spatial land use database for the 2021 water year (WY 2021). The primary objective of this effort was to produce a spatial land use database with accuracies exceeding 95% using remote sensing, statistical, and temporal analysis methods. This project is an extension of the 2014, 2016, 2018, 2019, and 2020 land use mapping, which classified over 14 million acres of land into irrigated agriculture and urban areas. Unlike the 2014 and 2016 datasets, the WY 2018, 2019, 2020, and 2021 datasets include multi-cropping and incorporates DWR ground-truth data from Siskiyou, Modoc, Lassen and Shasta counties. Land IQ integrated crop production knowledge with detailed ground truth information and multiple satellite and aerial image resources to conduct remote sensing land use analysis at the field scale. Individual fields (boundaries of homogeneous crop types representing cropped area, rather than legal parcel boundaries) were classified using a crop category legend and a more specific crop type legend. A supervised classification method using a random forest approach was used to classify delineated fields and was carried out county by county where training samples were available. Random forest approaches are currently some of the highest performing methods for data classification and regression. To determine frequency and seasonality of multiple-cropped fields, peak growth dates were determined for annual crops.

Data Source: Land IQ, www.LandIQ.com, California Department of Water Resources, Division of Regional Assistance Regional Offices: Northern, North Central, South Central and Southern Regional Offices, and Water Use Efficiency Branch (Sacramento Headquarters).

Statewide Crop Mapping - Datasets - California Natural Resources Agency Open Data

File Name: i15_Crop_Mapping_2021_Provisional.shp

Wildlife Habitat Relationship for Habitat Suitability

The California Wildlife Habitat Relationship (CWHR) System contains life history, geographic range, and management information for 712 species of amphibians, reptiles, birds, and mammals that occur within the state. It also contains detailed information on 59 habitat types and their spatial distribution. The core of the CWHR system is a database which relates these species to each of the habitats which support them. CWHR products aid in understanding, conserving, and managing California's wildlife. The system specifies habitat suitability based on species ranges (as of 2016), vegetation type, size/seral class, and canopy cover class. For more detailed information, see https://wildlife.ca.gov/Data/CWHR/Wildlife-Habitats.

CWHR – Vegetation Types

Data Vintage: 2021

Metric Definition and Relevance: This dataset represents the California Wildlife habitat relationships (CWHR) vegetation types for use in modeling biodiversity species richness and habitat for the SNV RRK project.

Data Resolution: 30m Raster

Data Units: Numeric (see crosswalk below)

Creation Method: This dataset was initially cross-walked to CWHR from the F3 model of forest type ("FORTYPE") and then updated to 2021, with disturbance changes from the eDaRT Mortality Magnitude Index (MMI). Since the F3 algorithm only models trees, to create a complete wall-to-wall dataset necessary to create biodiversity layers for the SNV RRK project area, it was decided to fill NoData areas with land cover types from the National Land Cover Database (NLCD). To differentiate NLCD's generalized "Deciduous Forest", "Evergreen Forest", "Mixed Forest", and "Shrub/Scrub", the CALVEG Existing Vegetation (eVeg) was used to identify vegetation types in greater detail.

Value	CWHR_Type	Habitat Type
100	JUN	Tree
200	PJN	Tree
300	PPN	Tree
400	SMC	Tree
500	SCN	Tree
600	WFR	Tree
700	RFR	Tree
800	LPN	Tree
900	RDW	Tree
1000	CPC	Tree
1100	VRI	Tree
1200	ASP	Tree
1300	MRI	Tree
1400	BOP	Tree
1500	MHW	Tree
1600	BOW	Tree
1700	ASC	Shrub
1800	URB	Urban
1900	DSW	Shrub
2000	DSC	Shrub
2100	AGS	Shrub
2200	BAR	Non_Vegetated
2300	CRP	Developed_Habitats
2400	MCH	Shrub
2500	BBR	Shrub
2600	SGB	Shrub
2700	DRI	Tree
2800	LAC	Water
2900	WTM	Herbaceous
3000	MCP	Shrub

3100	JPN	Tree
3200	EPN	Tree
3300	MHC	Tree
3400	LSG	Shrub
3500	PGS	Herbaceous
3600	FEW	Herbaceous
3700	ADS	Shrub
3800	RIV	Water
3900	DOR	Developed_Habitats
4000	PAS	Herbaceous
4100	JST	Tree
4200	CRC	Shrub
4400	VOW	Tree
4900	DFR	Tree

Data Source:

- Forest type designation from Forest Vegetation Simulator (FVS); F3 data outputs, Region 5, MARS Team; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- Ecosystem Disturbance and Recovery tracker (eDaRT) Mortality Magnitude Index (MMI), Region 5, MARS Team; 2021

File Name: f3veg100_NLCD_Integer.tif

CWHR – Size Class

Data Vintage: 2021

Metric Definition and Relevance: breakdown of stands by WHR diameter size class

Data Resolution: 30m Raster

Data Units: Tabular attributes

Creation Method: The F3 model generated raster surfaces for trees per acre by predefined non-overlapping CWHR diameter size class (Class 1 – 5).

- Size Class 0: "X" (non-forest)
- Size Class 1: Seedling (dbh is less than 1")
- Size Class 2: Sapling (dbh 1" to 6")
- Size Class 3: Pole tree (dbh 6" to 11")
- Size Class 4: Small tree (dbh 11" to 24")
- Size Class 5: Medium to large tree (dbh > 24")
- Size Class 6: Multi-layered trees of size class 5 over smaller trees of size class 3 or 4

2019 to 2022 Update: Tree density values for 2021 were adjusted independently for each CWHR diameter size class (Class 1 – 5). Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

$$2021\ TPA = 2019\ TPA - (2019\ TPA * MMI/100)$$

Although the assumption of direct correlation between canopy cover and TPA should be viewed with caution, it serves as a reasonable approximation for representative mixed conifer forests in the Sierra Nevada affected by the recent drought (Slaton et al. 2022).

Data Source: F3 data outputs, Region 5, MARS Team

File Name: Total3Run_SZ_NoMGT_2021_V20220512.tif

CWHR – Density by Canopy Cover

Data Vintage: 2021

Metric Definition and Relevance: the breakdown of stand density by WHR size class

Data Resolution: 30m Raster

Data Units: Thematic

Creation Method: The F3 model uses FVS to generate raster surface estimates of percent canopy cover of all live trees (>=0.1 inch dbh). There is a subtle difference between the two canopy cover rasters produced by F3:

- CPYCOVR = canopy percent cover based on stockable area for all live trees
- STANDCC = canopy percent cover (corrected for crown overlap) based on stockable area for all live trees

2019 to 2022 Update: The raster surface values were adjusted to 2021 using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The resulting value was subtracted from 2019 canopy cover to give 2021 canopy cover.

$$2021\ Canopy\ Cover = 2019\ Canopy\ Cover - (2019\ Canopy\ Cover * MMI/100)$$

It should be noted that the same eDaRT MMI-based adjustment was used for CPYCOVR and STANDCC. Because CPYCOVR is not corrected for crown overlap, the use of a loss estimate that is an absolute proportion per 30m pixel (i.e., the eDaRT MMI) may result in over- or underestimates for 2021 CPYCOVR, depending on location.

The adjusted canopy cover value from STANDCC has been binned according to the California Wildlife Habitat Relationships (CWHR) canopy closure categories*:

- Value 0 = < 10% Not determined/not applicable canopy (X)
- Value 1= 10.0-24.9% Sparse canopy (S)
- Value 2= 25.0-39.9% Open canopy (P)
- Value 3= 40.0-59.9% Moderate canopy (M)
- Value 4= > 60.0 Dense canopy(D)

*NOTE: There is an acknowledged difference between canopy closure and canopy cover. Canopy closure is a measure of the percentage of the sky hemisphere obscured by vegetation over a point, as opposed to canopy cover, the measure of canopy porosity averaged over a stand. The CWHR canopy crown closure percent categories have been used to classify the calculated Forest Canopy Cover data. Closure provides valuable information about the understory light, microclimate, and microhabitat environment at a specific location. See PSW-GTR-237 for more details.

Data Source: F3 data outputs, Region 5, MARS Team

File Name: Total3Run_STANDCC_NoMGT_2021_V20220512.tif

Aquatic

Lakes and Reservoirs

Data Vintage: 2022

Definition and Relevance: Waterbodies such as lake/pond features are represented in NHDWaterbody. They portray the spatial geometry and the attributes of the feature. These water polygons may have NHDFlowline artificial paths drawn through them to allow the representation of water flow direction. Other NHDWaterbody features are swamp/marsh, reservoir, playa, estuary, and ice mass. These data were used to erase areas of lakes and ponds from every raster metric in the SNV RRK project dataset.

Data Resolution: 30m

Data Units: Binary, 0/1

Creation Method: This dataset is a subset of vector polygon NHD waterbodies, encompassing the SNV RRK project boundary and converted to a raster grid at 30m and 300m resolutions based on existence/non-existence.

Data Source: USGS National Hydrography Dataset (NHD); https://www.usgs.gov/national-hydrography/national-hydrography-dataset

File Name: NHD_lakesReservoirs_2022_RRK.tif

Meadows

Data Vintage: 2019

Definition and Relevance: In practice, a meadow is an ecosystem type composed of one or more plant communities dominated by herbaceous species (Drew et. al. 2016). Meadows support plants that use surface water or shallow groundwater (generally at depths of less than 1 meter) during at least 2-4 weeks of the growing season. Woody vegetation like trees and shrubs may occur and be dense but are not dominant.

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method: The original UC Davis Center for Watershed Sciences meadow map (Fryjoff and Viers 2012) compiled 44 meadow maps from multiple sources. The effort delineated meadows, generally, as open areas greater than 1 acre with wetland vegetation and dominated by herbaceous vegetation. Woody vegetation was sometimes present to varying degrees but not dominating the meadow. Versions 2 and 3 retained nearly all of those meadow delineations and added more using the same criteria.

Version 2 – The Sierra Nevada Multi-source Meadow Polygons Compilation boundaries were updated using 'heads-up' digitization from high resolution (1m) NAIP imagery. Version 1 retained only polygons larger than one acre. In version 2, existing polygons were split, reduced in size, or merged, and additional polygons not captured were digitized. If split, the Original ID was maintained in one half and a new ID created for the other half. When adjacent meadows were merged, only one ID was retained and the unused ID was "decommissioned." Newly digitized meadows were assigned a new sequential ID.

Version 3 – Polygons for the entire Sierra National Forest (SNF) were replaced by more accurate data received from the GIS staff on the SNF. As in version 2, if a meadow was split the original ID from version 2 was retained for one half and a new sequential ID created for the other half if greater than 1 acre. Unused IDs were "decommissioned."

Data Source: Center for Watershed Sciences, UC Davis

File Name: meadows.gdb\Sierra_Nevada_MultiSource_Meadow_Polygons_Compilation_v3

Perennial and Intermittent Streams

Data Vintage: 2022

Definition and Relevance: USGS National Hydrography Dataset (NHD); Flowline is the fundamental flow network consisting predominantly of stream/river and artificial path vector features. It represents the spatial geometry and carries the attributes

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method: Data selected from NHD Flowline feature class to contain only FType code 460, StreamRiver (Perennial, Ephemeral, Intermittent) and clipped to the SNV RRK boundary.

Data Source: USGS National Hydrography Dataset (NHD); https://www.usgs.gov/national-hydrography/national-hydrography-dataset

File Name: NHD_Stream_2022.shp

Fire

Recent Fire Severity

Tier: 1

Data Vintage: 2021

Metric Definition and Relevance: Fire severity classification (low, moderate, high) that burned within the last 10 years (2012-2021).

Data Resolution: 30m raster

Data Units: Value, 1 to 3

Creation Method: The difference-adjusted relativized difference normalized burn ratio (RdNBR) was calculated using methods modified from Parks et al (2018). Fire perimeters were obtained from CAL FIRE's April 2021 fire perimeter database. A function for estimating basal area loss from RdNBR values was fit to data from Miller et al

(2009) using quasibinomial logistic regression and applied to the 2012-2021 fires. Estimated basal area loss was thresholded to represent low (< 25% loss), moderate (25% – 75% loss), and high (> 75% loss) burn severity. For areas where multiple sequential fires burned from 2012-2021 the maximum burn severity is reported.

- 1: Low Severity
- 2: Moderate Severity
- 3: High Severity

Data Source:

- Landsat 8, NASA
- Fire History (2021), CAL FIRE
- Postfire mortality data, Miller et al. 2009

File Name: fire_severity_class_max_2012to2021_all_CA_v2.tif

Potential Operational Delineations

Data Vintage: 2016

Definition and Relevance: Potential Operational Delineations (PODs) are spatial units or containers defined by potential fire control features, such as roads and ridge tops, within which relevant information on forest conditions, ecology, and fire potential can be summarized. The Rocky Mountain Research Station Wildfire Risk Management Science (WRMS) Team co-developed PODs to pre-plan for fire using a risk management approach, and to give land managers a formal process for developing landscape-scale wildfire response options before fires start. PODs combine local fire knowledge with advanced spatial analytics to help managers develop a common understanding of risks, management opportunities, and desired outcomes to determine fire management objectives.

PODs vary in size, are drawn irrespective of jurisdictional boundaries, and correspond to potential control points for a fire such as roads, ridgelines, drainages, previous fuel treatment boundaries, recent burns, or anything else that might give firefighters on the ground an advantage. Where PODs are preplanned, they guide managers in developing initial response strategies and tactics in a particular area in the event of ignition.

The PODs provided here represent conditions as of about 2016. Each forest in CA is the keeper of its own POD data attributes, and the majority of the POD networks on the Sierras are in revision or in need of revision using the current participatory process framework (post-2016). The Inyo, Stanislaus, Tahoe Basin, Lassen, Tahoe, and Eldorado POD networks are being updated. Others will be updated as staff availability permits.

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method: The process of developing PODs is done collaboratively by local wildland fire managers, stakeholders, and scientists. Collaborators identify a network of best available control features, often using analytical tools to assess the feature’s quality and suitability. When paired with a wildfire risk assessment, PODs can be used to quantify and summarize risk into strategic response zones that provide the starting point for strategic planning of incident response.

PODs will need updating through a collaborative process where fire scientists work with local planners and community members to provide a spatial analysis of the entire National Forest or other planning area to delineate/update suitable potential control locations, update the quantitative risk assessment of high resource values, and assess suppression difficulty across the landscape. Updated information will enable delineation or improvement of the POD layout.

Data Source: USDA Forest Service RMRS Wildfire Risk Management Science Team https://www.fs.usda.gov/rmrs/groups/wildfire-risk-management-science-team

File Name: PODs.shp

Wildland Urban Interface

Data Vintage: 2022

Definition and Relevance: The wildland urban interface (WUI) is the area where urban development is in close proximity to wildland vegetation. WUI data for the conterminous U.S. based on 125 million building locations where buildings intermingle with or abut wildland vegetation according to the Federal Register definitions of the WUI.

Data Resolution: 30m Raster

Data Units: Categorical

Creation Method: The current delineation of the WUI (Carlson et al. 2022) uses a mapping algorithm with definitions of the WUI; two classes of WUI were identified:

1. the intermix, where there is at least 50% vegetation cover surrounding buildings
2. the interface, where buildings are within 2.4 km (1.5 miles) of a patch of vegetation at least 5 km^2 in size that contains at least 75% vegetation.

Both classes required a minimum building density of 6.17 buildings per km^2 (using a range of circular neighborhood sizes).

Data Source: USGS ScienceBase Data Catalog; https://www.sciencebase.gov/catalog/item/617bfb43d34ea58c3c70038f

File Name: MSB_WUI_100m.tif

Housing Unit Density

Data Vintage: 01/2020

Metric Definition and Relevance: HUDen is a raster of housing-unit density measured in housing units per square kilometer. The HUDen raster was generated using population and housing-unit count and data from the U.S. Census Bureau, building footprint data from Microsoft, and land cover data from LANDFIRE.

Data Resolution: 30m Raster

Data Units: Housing units per square kilometer

Creation Method: Generate the HUDen raster from the building points. We first converted the building points to a 30-m raster where the raster value is the sum of the housing-units-per-centroid attribute of all building centroids within each raster grid cell. We then generated a smoothed density raster using a three-step process: 1) calculate a 200-m radius moving-window sum of the 30-m housing-unit count raster; 2) calculate a 200-m radius moving-window sum of habitable land cover (in sq km), where habitable land cover is all land covers except open water and permanent-snow/ice; and 3) divide the smoothed housing-unit count raster by the smoothed habitable land cover raster to generate housing unit density in housing units/sq km. To produce the final integer version of the HUDen raster, we set values less than 0.1 HU/sq km to zero, values between 0.1 and 1.5 to a value of 1 HU/sq km, and rounded all other values to the nearest integer.

Data Source: Pyrologix, LLC

File Name: HUden_2020.tif

Data Disclaimers

The user is responsible to verify the limitations of the geospatial data and to use the data accordingly. For all data layers, please check each data source and adhere to any limitations established by the data creator. In general, adhere to the terms for use listed at the bottom of this section.

The authors make no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness, or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions or boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and land users should exercise due caution. The data are dynamic and may change over time.

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original.

No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything this license permits.

No commercial use – the user is responsible for acknowledging those data layers within this RRK (as determined by the source of the data) that are not permitted for commercial use.

California Department of Fish and Wildlife (CDFW)

The state makes no claims, promises, or guarantees about the accuracy, completeness, reliability, or adequacy of these data and expressly disclaims liability for errors and omissions in these data. No warranty of any kind, implied, expressed or statutory, including but not limited to the warranties of non-infringement of third-party rights, title, merchantability, fitness for a particular purpose, and freedom from computer virus, is given with respect to these data.

Area of Conservation Emphasis (ACE)

The ACE data is subject to certain assumptions and limitations that must be considered in any use or application of the data. All ACE data layers are limited by the accuracy and scale of the input data. ACE is a compilation of the best available scientific information; however, many of these datasets are not comprehensive across the landscape, may change over time, and should be revised and improved as new data become available.

The user accepts sole responsibility for the correct interpretation and use of these data and agrees not to misrepresent these data. CDFW makes no warranty of any kind regarding these data, express or implied. By downloading these datasets, the user understands that these data are in draft condition and subject to change at any time as new information becomes available. The user will not seek to hold the State or the Department liable under any circumstances for any damages with respect to any claim by the user or any third party on account of or arising from the use of data or maps. CDFW reserves the right to modify or replace these datasets without notification.

The ACE maps display biological and recreational values based on available data and constrained by the limitations of the data. The values may be influenced by level of survey effort in a given area. The ACE data represent broad-scale patterns across the landscape, and the value of any single watershed should be interpreted with caution. ACE is a decision-support tool to be used in conjunction with species-specific information and local-scale conservation prioritization analyses.

The ACE maps do not replace the need for site-specific evaluation of biological resources and should not be used as the sole measure of conservation priority during planning. No statement or dataset shall by itself be considered an official response from a state agency regarding impacts to wildlife resulting from a management action subject to the California Environmental Quality Act (CEQA).

Biogeographic Information and Observation System (BIOS)

Use of this dataset requires prior approval by the primary contact. Recognition that the data set was created and provided by the California Department of Fish and Wildlife, and that any questions regarding the data should be addressed to the contact person listed in the metadata.

California Department of Water Resources

Groundwater basins and subbasins are defined by the California Department of Water Resources as last modified by the Basin Boundary Emergency Regulation adopted on October 21, 2015. The file is in ESRI geodatabase format and is intended for use with compatible GIS software. Groundwater basins are represented as polygon features and designated on the basis of geological and hydrological conditions - usually the occurrence of alluvial or unconsolidated deposits. When practical, large basins are also subdivided by political boundaries, as in the Central Valley. Basins are named and numbered per the convention of the Department of Water Resources. The associated data are considered DWR enterprise GIS data, which meet all appropriate requirements of the DWR GIS Spatial Data Standards. DWR makes no warranties or guarantees, either expressed or implied, as to the completeness, accuracy or correctness of the data, nor accepts or assumes any liability arising from or for any incorrect, incomplete or misleading subject data.

Department of Forestry and Fire Protection (CALFIRE)

The State of California and the Department of Forestry and Fire Protection make no representations or warranties regarding the accuracy of data or maps. The user will not seek to hold the State or the Department liable under any circumstances for any damages with respect to any claim by the user or any third party on account of or arising from the use of data or maps.

California Farmland Mapping and Monitoring Program (FMMP)

The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of these data or maps. Neither the State nor the Department shall be liable under any circumstances for direct, indirect, special, incidental or consequential damages with respect to any claim by any user or any third party on account of or arising from the use of these data or maps.

This data does not reflect general plan or zoning designations, city limit lines, changing economic or market conditions, or other factors which may be taken into consideration when land use policies are determined. This data is not designed to be used for parcel specific planning purposes due to its scale and the size of the minimum mapping unit (10 acres).

California Forest Observatory (Salo Sciences)

Welcome to the California Forest Observatory, a forest monitoring platform that maps vegetation fuels and wildfire hazard across the state, operated by Salo Sciences, Inc. ("Salo", "we", "us", "our") and the product of a collaboration between Salo, Planet Labs, Inc., and Vibrant Planet, LLC (collectively, the "Collaborators"). Please read on to learn the rules and restrictions that govern your use of our website(s), products, services, data, applications, and application programming interfaces (the "Services"). If you have any questions, comments, or concerns regarding these terms or the Services, please contact us at info@forestobservatory.com.

These Terms of Use (the "Terms") are a binding contract between you and Salo as operator of the Services. You must agree to and accept all of the Terms, or you don't have the right to use the Services. Your using the Services in any way means that you agree to all of these Terms, and these Terms will remain in effect while you use the Services. These Terms include the provisions in this document, As well as those in the Privacy Policy and API Terms.

Please read these Terms carefully. They cover important information about the Services provided to you, including information about future changes to these Terms, limitation of liability, a class action waiver, and resolution of disputes by arbitration instead of in court. For complete Terms of Use visit https://forestobservatory.com/legal.html.

California Office of Environmental Health Hazard Assessment (OEHHA)

The State makes no claims, promises, or guarantees about the accuracy, completeness, reliability, or adequacy of these data and expressly disclaims liability for errors and omissions in these data. No warranty of any kind, implied, expressed, or statutory, including but not limited to the warranties of non-infringement of third party rights, title, merchantability, fitness for a particular purpose, and freedom from computer virus, is given with respect to these data.

Center for Ecosystem Climate Solutions (CECS) – UC Irvine

The University of California ("UC") makes the materials on this website available pursuant to the following disclaimers: the materials are offered "as is"; user assumes any and all risks, of any kind or amount, of using these materials; user shall use the materials only in accordance with law; user releases, waives, discharges and promises not to sue UC, its directors, officers, employees or agents, from liability from any and all claims, including the negligence of UC, resulting in personal injury (including death), accidents or illnesses, property loss, as well as any and all loss of business and/or profit in connection with user's use of the materials; and user shall indemnify and hold UC harmless from any and all claims, actions, suits, procedures, costs, expenses, damages, and liabilities, including attorney's fees, arising out of user's use of the materials and shall reimburse UC for any such incurred expenses, fees or costs.

Landfire (USFS/USDOI)

LANDFIRE - LANDFIRE (LF), Landscape Fire and Resource Management Planning Tools, is a shared program between the wildland fire management programs of the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior, providing landscape scale geo-spatial products to support cross-boundary planning, management, and operations. LF data products provide data for landscape assessment, analysis, and management. Data and information serve as important data sets in decision support with efforts such as identification of areas with similar characteristics, prioritization exercises, modeling capacity and potential, and improving collaboration between landowners with common data sets and analytics. See https://landfire.gov/index.php for details on the various products from LANDFIRE.

Open Data Commons Open Database License (ODbL)

Open Data Commons is not a law firm and does not provide legal services of any kind.

Open Data Commons has no formal relationship with you. Your receipt of this document does not create any kind of agent-client relationship. Please seek the advice of a suitably qualified legal professional licensed to practice in your jurisdiction before using this document.

No warranties and disclaimer of any damages. This information is provided 'as is', and this site makes no warranties on the information provided. Any damages resulting from its use are disclaimed.

Open Street Map

This data is made available under the Open Database License: http://opendatacommons.org/licenses/odbl/1.0/. Any rights in individual contents of the database are licensed under the Database Contents License: http://opendatacommons.org/licenses/dbcl/1.0/. OSM data are free to copy, distribute, transmit and adapt. OpenStreetMap® is open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF).

Pyrologix

The user must be aware of data conditions and must ultimately bear responsibility for the appropriate use of the information with respect to possible errors, possible omissions, map scale, data collection methodology, data currency, and other conditions specific to certain data.

This 2022 dataset is an update produced by Pyrologix for the Bureau of Land Management (BLM) California State Office. The original 2020 dataset was developed by Pyrologix for the USFS Pacific Southwest Region. Citation for this data is in the References section below.

USDA Forest Service (USFS)

The following Use Constraint applies: The USDA Forest Service makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness, or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions or boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and users should exercise due caution. The data are dynamic and may change over time. The user is responsible to verify the limitations of the geospatial data and to use the data accordingly.

USDA Forest Service (USFS) – Forest Inventory and Analysis (FIA) Program

In addition to the USDA Forest Service Use Constraint, the following Distribution Liability applies to F3 products and F3 derived products: The USDA Forest Service manages resource information and derived data as a service to users of USDA Forest Service digital geographic data. The USDA Forest Service is in no way condoning or endorsing the application of these data for any given purpose. It is the sole responsibility of the user to determine whether or not the data are suitable for the intended purpose. It is also the obligation of the user to apply those data in an appropriate and conscientious manner. The USDA Forest Service provides no warranty, nor accepts any liability occurring from any incorrect, incomplete, or misleading data, or from any incorrect, incomplete, or misleading use of these data.

Any F3 derived products should include credit to the USDA Forest Service, Pacific Northwest Research Station, FIA Program as well as the above Use Constraint and Distribution Liability disclaimers. The credit should cite the database description and user guide following Burrill et al. 2018.

US Fish and Wildlife Service (USFWS)

The use of trade, product, industry or firm names is for informative purposes only and does not constitute an endorsement by the U.S. Fish and Wildlife Service. Link to non-Service Web sites do not imply any official U.S. Fish and Wildlife Service endorsement of the opinions or ideas expressed therein or guarantee the validity of the information provided. Base cartographic information used as part of the Wetlands Mapper has been provided through a license agreement with ESRI and the Department of the Interior.

U.S. Geological survey (USGS)

Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

Additional Resources

California Department of Fish and Wildlife Areas of Conservation Emphasis program: https://wildlife.ca.gov/Data/Analysis/Ace

California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0 personal computer program. Sacramento, CA. http://wildlife.ca.gov/Data/CWHR

California Office of Environmental Health Hazard Assessment CalEnviroScreen 4.0 report: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

Forest Vegetation Simulator: https://www.fs.usda.gov/fvs/index.shtml and Essential FVS User's Guide: https://www.fs.usda.gov/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf

Monitoring Trends in Burn Severity (MTBS) program: https://www.mtbs.gov/

Multi-Resolution Land Characteristics Consortium (MRLC): https://www.mrlc.gov/

Oregon State University Environmental Monitoring, Analysis, and Process Recognition (eMapR) Lab: http://emapr.ceoas.oregonstate.edu/

Oregon State University PRISM Climate Group: https://prism.oregonstate.edu/

Rapid Assessment of Vegetation Condition after Wildfire (RAVG): https://burnseverity.cr.usgs.gov/ravg/

USDA Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis Program: https://www.fia.fs.usda.gov/

References

Abood S.A., Spencer L., Wieczorek M., 2022. U.S. Forest Service national riparian areas base map for the conterminous United States in 2019. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2019-0030

Albano, C.M., McClure, M.L., Gross, S.E., Kitlasten, W., Soulard, C.E., Morton, C., Huntington, J., 2019. Spatial patterns of meadow sensitivities to interannual climate variability in the Sierra Nevada. *Ecohydrology.* v12(7), e2128. https://doi.org/10.1002/eco.2128

Bernal, A.A., Stephens, S.L., Collins, B.M., Battles, J.J., 2022. Biomass stocks in California's fire-prone forests: mismatch in ecology and policy. *Environmental Research Letters*. v17, (044047). https://doi.org/10.1088/1748-9326/ac576a

Burrill, E.A., Wilson, A.M., Turner, J.A., Pugh, S.A., Menlove, J., Christensen, G., Conkling, B.L., David, W., 2018. The Forest Inventory and Analysis Database: database description and user guide version 8.0 for Phase 2. U.S. Department of Agriculture, Forest Service. 946 p. https://www.fia.fs.usda.gov/library/database-documentation/index.php#FIADB

California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0 personal computer program. Sacramento, CA. https://wildlife.ca.gov/Data/CWHR

Carlson, A.R., Helmers, D.P., Hawbaker, T.J., Mockrin, M.H., Radeloff, V.C., 2022. Wildland-urban interface maps for the conterminous U.S. based on 125 million building locations. *Ecological Applications.* v32(5), e2597. https://doi.org/10.1002/eap.2597 and as U.S. Geological Survey data release: https://doi.org/10.5066/P94BT6Q7

Christensen, G.A., Gray, A.N., Kuegler, O., Tase, N.A., Rosenberg, M., Loeffler, D., Anderson, N., Stockmann, K., Morgan, T.A., 2019. *AB 1504 California Forest Ecosystem and Harvested Wood Product Carbon Inventory: 2017 Reporting Period. Final Report*. U.S. Forest Service agreement no. 18-CO-11052021-214, 17-CO-11261979-086, California Department of Forestry and Fire Protection agreement no. 8CA04056 and 8CA03714 and the University of Montana. Sacramento, CA: California Department of Forestry and Fire Protection and California Board of Forestry and Fire Protection. 539 p. https://www.oregon.gov/ODF/ForestBenefits/Documents/Forest%20Carbon%20Study/Report-CA-1504-forest-ecosys-HWP-CA-2017-13feb19.pdf

Cisneros, R., Schweizer, D., Preisler, H., Bennett, D. H., Shaw, G., Bytnerowicz, A., 2014. Spatial and seasonal patterns of particulate matter less than 2.5 microns in the Sierra Nevada Mountains, California. *Atmospheric Pollution Research*. v5(4), (581-590). https://doi.org/10.5094/APR.2014.067

Cowardin, L.M., Carter, V., Golet, F.C., LaRoe, E.T., 1979 Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS 79/31. 103 pp. https://pubs.er.usgs.gov/publication/2000109

Daly, C., Neilson, R.P., Phillips, D.L., 1994. A statistical topographic model for mapping climatological precipitation. Over mountainous terrain. *Journal of Applied Meteorology and Climatology.* v33(2), (140-158). https://doi.org/10.1175/1520-0450(1994)033%3C0140:ASTMFM%3E2.0.CO;2

Drew, W.M., Hemphill, N., Keszey, L., Merrill, A., Hunt, L., Fair, J., Yarnell, S., Drexler, J., Henery, R., Wilcox, J., Burnett, R., Podolak, K., Kelley, R., Loffland, H., Westmoreland, R., Pope., K., 2016. Sierra Meadows Strategy., Sierra Meadows Partnership Paper 1: pp 40. https://sierrafund.org/wp-content/uploads/Sierra_Meadow_Strategy_full_report_SHAREABLE_mid.pdf

Enquist, B.J., 2002. Universal scaling in tree and vascular plant allometry: toward a general quantitative theory linking plant form and function from cells to ecosystems. *Tree Physiology*. v22(15-16), (1045-1064). https://doi.org/10.1093/treephys/22.15-16.1045

Finney, M.A., McHugh, C.W., Grenfell, I.C., Riley, K.L., Short, K.C., 2011. A simulation of probabilistic wildfire risk components for the continental United States. *Stochastic Environmental Research and Risk Assessment.* v25(7), (973-1000). https: //doi.org/10.1007/s00477-011-0462-z

Flint, L.E., Flint, A.L., 2014. California Basin Characterization Model: A Dataset of Historical and Future Hydrologic Response to Climate Change, (ver. 1.1, May 2017): U.S. Geological Survey Data Release, https://doi.org/10.5066/F76T0JPB

Fryjoff-Hung & Viers, 2012. Sierra Nevada Multi-Source Meadow Polygons Compilation (v 1.0), Center for Watershed Sciences, UC Davis. December 2012. https://meadows.ucdavis.edu/resources/341

Girvetz, E. H., Greco, S. E., 2007. How to define a patch: a spatial model for hierarchically delineating organism-specific habitat patches. *Landscape Ecology*. v22, (1131-1142). https://doi.org/10.1007/s10980-007-9104-8

Goodwin, M.J., Zald, H.S.J., North, M.P., Hurteau, M.D., 2021. Climate-driven tree mortality and fuel aridity increase wildfire's potential heat flux. *Geophysical Research Letters*. 48, e2021GL094954. https://doi.org/10.1029/2021GL094954

Gutierrez, R.J., Manley, P.N., Stine, P.A. tech. eds., 2017. The California spotted owl: current state of knowledge. Gen. Tech. Rep. PSW-GTR-254. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 294 p. https://www.fs.usda.gov/psw/publications/documents/psw_gtr254/

Higuera, P. E., Abatzoglou, J. T., 2020. Record-setting climate enabled the extraordinary 2020 fire season in the western United States. *Global Change Biology*. v27(1), (1-2). https://doi.org/10.1111/gcb.15388

Huang, S., Ramirez, C., Kennedy, K., Mallory, J., 2017. A New Approach to Extrapolate Forest Attributes from Fields Inventory with Satellite and Auxiliary Data Sets. *Forest Science*. v63(2), (232-240). https://doi.org/10.5849/forsci.16-028

Huang, S., Ramirez, C., McElhaney, M., Evans, K., 2018. F3: Simulating spatiotemporal forest change from field inventory, remote sensing, growth modeling, and management actions. *Forest Ecology and Management*. v415-416, (26-37). https://doi.org/10.1016/j.foreco.2018.02.026

Huang, S., Ramirez, C., Conway, S., Evans, K., Chu, C., McElhaney, M., Hart, R., Kennedy, K., Kohler, T., Yao, Z., 2019. LITIDA: a cost-effective non-parametric imputation approach to estimate LiDAR-detected tree diameters over a large heterogeneous area. *Forestry*. v92, (206-218). https://doi.org/10.1093/forestry/cpz002

Jeronimo, S. M. A., Kane, V. R., Churchill, D. J., Lutz, J. A., North, M. P., Asner, G. P., Franklin, J. F., 2019. Forest structure and pattern vary by climate and landform across active-fire landscapes in the montane Sierra Nevada. *Forest Ecology and Management*. v437, (70-86). https://doi.org/10.1016/j.foreco.2019.01.033

Keyantash, John & National Center for Atmospheric Research Staff (Eds). Last modified 07 August 2018. "The Climate Data Guide: Standardized Precipitation Index (SPI)." Retrieved 2022 from https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi

Koltunov, A., Ramirez, C. M., Ustin, S. L., Slaton, M., Haunreiter, E., 2020. eDaRT: The Ecosystem Disturbance and Recovery Tracker system for monitoring landscape disturbances and their cumulative effects. *Remote Sensing of Environment*. v238(1), (111482). https://doi.org/10.1016/j.rse.2019.111482

Long, J. W., Tarnay, L. W., North, M. P., 2018. Aligning Smoke Management with Ecological and Public Health Goals. *Journal of Forestry*. v116(1), (76-86). https://doi.org/10.5849/jof.16-042

Madakumbura, G.D., Goulden, M.L., Hall, A., Fu, R., Moritz, M.A., Koven, C.D., Kueppers, L.M., Norlen, C.A., Randerson, J.T., 2020. Recent California tree mortality portends future increase in drought-driven forest die-off. *Environmental Research Letters.* v15(12), e124040. https://doi.org/10.1088/1748-9326/abc719

Mandelbrot, B. B. 1977. *Fractals: Form, Chance, and Dimension*. San Francisco. W. H. Freeman and Company.

Manley, P., Wilson, K., Povak, N., 2020. Framework for promoting socio-ecological resilience across forested landscapes in the Sierra Nevada. Final report to the Sierra Nevada Conservancy for the Tahoe Central Sierra Initiative. Sierra Nevada Conservancy, Auburn, California. 30 pp. https://www.fs.usda.gov/psw/topics/restoration/tcsi/ and https://sierranevada.ca.gov/wp-content/uploads/sites/326/2020/10/TCSIframework.pdf

Manley, P.N., Povak, N.A., Wilson, K., 2022. A framework for socio-ecological resilience to inform climate change management strategies across forested landscapes. In review. *Ecosphere*.

McGarigal, K., Maritza, M., Estes, B., Tierney, M., Walsh, T., Thane, T., Safford, H., Cushman, S. A., 2018. Modeling Historical Range of Variability and Alternative Management Scenarios in the Upper Yuba River Watershed, Tahoe National Forest, California. Gen. Tech. Rep. RMRS-GTR-385. https://www.fs.usda.gov/rm/pubs_series/rmrs/gtr/rmrs_gtr385.pdf

McGarigal, K., Marks, B.J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122 p. https://www.fs.usda.gov/pnw/publications/fragstats-spatial-pattern-analysis-program-quantifying-landscape-structure

Miller, J.D., Knapp, E.E., Key, C.H., Skinner, C.N., Isbell, C.J., Creasy, R.M., Sherlock, J.W., 2009. Calibration and validation of the relative differenced Normalized Burn Ratio (RdNBR) to three measures of fire severity in the Sierra Nevada and Klamath Mountains, California, USA. *Remote Sensing of Environment.* v113(3), (645-656). https://doi.org/10.1016/j.rse.2008.11.009

Ng, J., North, M. P., Arditti, A. J., Cooper, M., R., Lutz, J. A., 2020. Topographic variation in tree group and gap structure in Sierra Nevada mixed-conifer forests with active fire regimes. *Forest Ecology and Management*. v472, (118220). https://doi.org/10.1016/j.foreco.2020.118220

North, M. ed., 2012. Managing Sierra Nevada forests. Gen. Tech. Rep. PSW-GTR-237. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 184 p. https://www.fs.fed.us/psw/publications/documents/psw_gtr237/

North, M.P., Tompkins, R.E., Bernal, A.A., Collins, B.M., Stephens, S.L., York, R.A., 2022. Operational resilience in western US frequent-fire forests. *Forest Ecology and Management.* v507(12004). https://doi.org/10.1016/j.foreco.2021.120004

Parks, S.A., Holsinger, L.M., Voss, M.A., Loehman, R.A., Robinson, N.P., 2018. Mean composite fire severity metrics computed with Google Earth Engine offer improved accuracy and expanding mapping potential. *Remote Sensing.* v10(6), 879. https://doi.org/10.3390/rs10060879

Safford, H. D., Van de Water, K. M, 2014. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California. Res. Pap. PSW-RP-266. https://www.fs.usda.gov/psw/publications/documents/psw_rp266/psw_rp266.pdf

Scott, J.H., 2020. A deterministic method for generating flame-length probabilities. In: Hood, S.M., Drury, S., Steelman, T., Steffens, R., [eds.]. 2020. Proceedings of the Fire Continuum-Preparing for the future of wildland fire; 2018 May 21-24; Missoula, MT. Proceedings RMRS-P-78. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 358 p. https://www.fs.usda.gov/treesearch/pubs/62336

Scott, J. H., Thompson, M. P., Calkin, D. E., 2013. A wildfire risk assessment framework for land and resource management. Gen. Tech. Rep. RMRS-GTR-315. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research station. 83 p. https://doi.org/10.2737/rmrs-gtr-315 ; https://www.fs.usda.gov/treesearch/pubs/56265

Slaton, M.R., Warren, K., Koltunov, A., Smith, S., 2022. Chapter 12, Accuracy assessment of insect and disease survey and eDaRT for monitoring forest health. In: Potter, K.M., Conkling, B.L. Forest health monitoring: national status, trends, and analysis 2021. GTR-SRS-266. Asheville, NC: USDA Forest Service, Southern Research Station. 193 p. https://doi.org/10.2737/SRS-GTR-266

Stephens, S. L., Bernal, A. A., Collins, B. M., Finney, M. A., Lautenberger, C., Saah, D., 2022. Mass fire behavior created by extensive tree mortality and high tree density not predicted by operational fire behavior models in the southern Sierra Nevada. *Forest Ecology and Management*. v518, (120258). https://doi.org/10.1016/j.foreco.2022.120258

Stewart J.A.E., van Mantgem, P.J., Young, D.J.N., Shive, K.L., Preisler, H.K., Das, A.J., Stephenson, N.L., Keeley, J.E., Safford, H.D., Wright, M.C., Welch, K.R. & Thorne, J.H., 2021. Effects of postfire climate and seed availability on postfire conifer regeneration. Ecological Applications. v31(3), e02280. https://doi.org/10.1002/eap.2280

Stewart J.A.E. Postfire Conifer Reforestation Planning Tool. https://reforestationtools.org/postfire-conifer-reforestation-planning-tool/

UC Davis, Center for Watershed Sciences & USDA Forest Service, Pacific Southwest Region, 2017. Sierra Nevada MultiSource Meadow Polygons Compilation (v 2.0), Vallejo, CA, Regional Office: USDA Forest Service. 2017. http://meadows.ucdavis.edu/

U.S. Department of Commerce, Census Bureau (USDCCB), 2021. *2020 Census State Redistricting Data (Public Land 94-171) Summary File*, [online resource], https://www.census.gov/programs-surveys/decennial-census/about/rdo/summary-files.html

USDA Forest Service. 2018. Toward Shared Stewardship Across Landscapes: An Outcome-Based Investment Strategy. Publication FS-1118. https://www.fs.usda.gov/sites/default/files/toward-shared-stewardship.pdf

USDA Forest Service. 2019. Conservation Strategy for the California spotted owl (*Strix occidentalis occidentalis*) in the Sierra Nevada. Publication R5-TP-043. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd624135.pdf

USDA Forest Service. 2020. Region 5 Black-Backed Woodpecker Habitat Analysis. Internal Report, Region 5 Mapping and Remote Sensing (MARS) Team

USDA Forest Service, Pacific Northwest Research Station, Forest Inventory and Analysis Program.

U.S. Fish and Wildlife Service. Revised 2019 (2009). A System for Mapping Riparian Areas in The Western United States. Ecological Services Division of Budget and Technical Support Branch of Geospatial Mapping and Technical Support. Falls Church, VA. https://www.fws.gov/wetlands/documents/A-System-for-Mapping-Riparian-Areas-in-The-Western-United-States-2019.pdf

Van de Water, K. M., Safford H. D., 2011. A Summary of Fire Frequency Estimates for California Vegetation Before Euro-American Settlement. *Fire Ecology*. v7(3), (26-58). https://fireecology.springeropen.com/track/pdf/10.4996/fireecology.0703026.pdf

Volger, K.C., Brough, A., Moran, C.J., Scott, J.H., Gilbertson-Day, J.W., 2021. Contemporary Wildfire Hazard Across California. Prepared for: Pacific Southwest Region, USDA Forest Service. Available at: http://pyrologix.com/reports/Contemporary-Wildfire-Hazard-Across-California.pdf

Wang J.A., Randerson J. T., Goulden M.L., Knight C.A., & Battles, J.J. (2022). Losses of tree cover in California driven by increasing fire disturbance and climate stress. AGU Advances, 3, e2021AV000654. https://doi.org/10.1029/2021AV000654

Wayman, R.B., Safford, H.D., 2021. Recent bark beetle outbreaks influence wildfire severity in mixed-conifer forests of the Sierra Nevada, California, USA. *Ecological Applications*. v31(3), e02287. https://doi.org/10.1002/eap.2287

Sierra Nevada Regional Resource Kit Citation

Sierra Nevada RRK: https://rrk.sdsc.edu/snv

Young-Hart, L., Stine, P., Manley, P., Clark, C., Slaton M., Stewart J., Tarnay L., Bistritz, L., Goulden, M., Kuskulis, E., Ramirez, C., Young, D., 2023. *SN_RRK Metric Dictionary*. 93 p.