SIERRA NEVADA REGIONAL RESOURCE KIT METRIC DICTIONARY

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

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INTRODUCTION

WHAT IS THE ACCEL EFFORT?

The USDA Forest Service, in collaboration with the California Natural Resources Agency and other partners, 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 "Strategy for Shared Stewardship" (2018), 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, referred to as the ACCEL project (for accelerating pace and scale of treatments), combines the expertise and experience of research and management to build this library of data on landscape conditions.

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 is comprised of 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 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 the Sierra Nevada, 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.

INTENDED PURPOSE

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.

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:

- 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
- Where reasonable, a desired management target

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.

REFERENCE CONDITIONS

Metric values in themselves do not convey information that is useful to management. Information conveyed by metric values is based on some frame of reference – be it ecological, social, cultural, or economic. Although many different frames of reference can be generated for any given metric or suites of metrics for a given location, there are some general rules of thumb that can be used as a frame of reference to guide basic interpretations of conditions. Reference conditions provide a necessary guide for how to put metrics into common units so that they can be compared and combined to make inferences about elements and pillars.

For the Regional Resource Kits, in addition to metrics being described in term of actual values, they are also described in terms of normalized values which range from -1 to 1. Normalized values serve to put each metric into the same range of values, with -1 generally representing less favorable conditions, and +1 generally representing more favorable conditions, in terms of resilience to disturbance, with particular emphasis on stresses associated with climate change. For most individual metrics, low values are less favorable and high values more favorable, but there are some exceptions in regard to resilience to climate change. The rescaling of all metrics from -1 to 1 in this manner then enables users to evaluate multi-metric conditions by summing or averaging the normalized values to represent elements, pillars, and overall ecosystem conditions.

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 interested readers become familiar with the afore-linked scientific articles.

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. The following flowchart from the F3 article has been included to help illustrate the full F3 process.

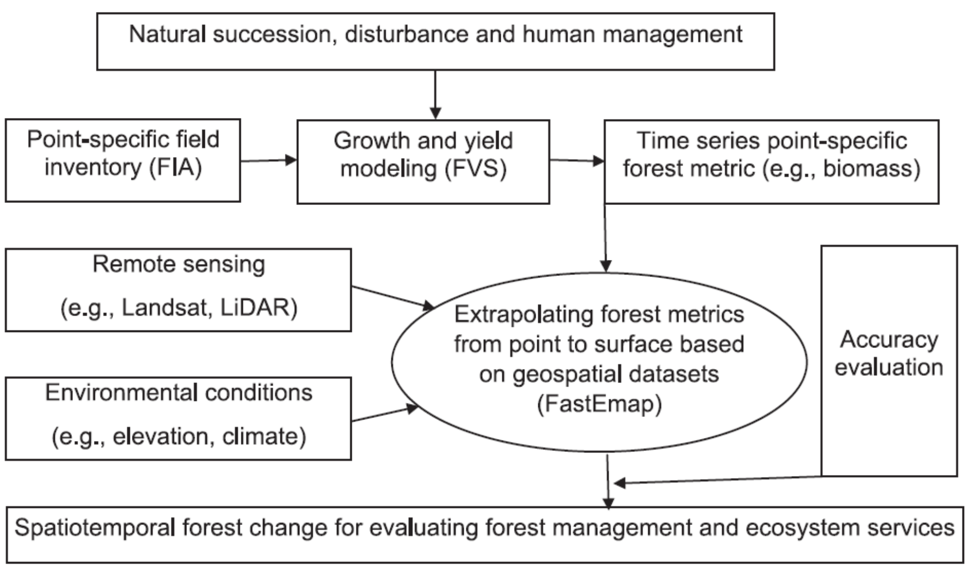

Fig. 1. Flowchart of F^3 modeling framework.

** Due to confidentiality requirements, the actual FIA plot locations have been perturbed (fuzzed) to ensure confidentiality is maintained.*

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 ACCEL, 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 and Disturbance Recovery Tracker (eDaRT; Koltunov et al. 2019), 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 and Ustin 2007, Koltunov et al. 2009, Koltunov et al. 2019). 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 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 subannual 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.

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 WUI data layer is provided as part of the project; the defense zone is defined as within ¼ mile of development (infrastructure) with an additional 1 ¼ miles beyond the defense zone defining the threat zone. 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 fire risk in the wildland urban interface (WUI) defense and threat zones.

STRUCTURE EXPOSURE SCORE

Metric Definition and Relevance: This metric combines two data layers; one is the Wildland Urban Interface (WUI) as defined by Carlson et al. 2022, and a second data layer, Structure Exposure Score (SES), developed by Pyrologix LLC. The WUI includes the intermix and interface zones which collectively identify areas where structures occur. The distance selected for the interface definition is based on research from the California Fire Alliance suggesting that this is the average distance firebrands can travel from an active wildfire front. 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. The data are current through 2021.

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. This metric represents SES for WUI areas only.

Data Resolution: 300m Raster

Data Units: Relative index, 10 classes

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).

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 Pyrolgix 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 120-m 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.

The final step was to overlay the 2022 version of SES with the 2022 footprint of the WUI.

Data Source:

- Pyrologix, LLC
- WUI (USGS)

File Name: StructureExposureScore_WUI_2022.tif ;StructureExposureScore_WUI_2022_300m_base.tif; StructureExposureScore_WUI_2022_30m_normalized.tif; StructureExposureScore_WUI_2022_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = low, -1 = high)

DAMAGE POTENTIAL

Metric Definition and Relevance: This metric combines two data layers; one is the Wildland Urban Interface (WUI) as defined by Carlson et al. 2022, and a second data layer, Damage Potential (DP), developed by Pyrologix LLC. The WUI includes the intermix and interface zones which collectively identify areas where structures occur. The distance selected for the interface definition is based on research from the California Fire Alliance suggesting that this is the average distance firebrands can travel from an active wildfire front. 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. The data are current through 2021.

Data Resolution: 300m Raster

Data Units: Relative index, low to high

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).

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 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 Pryologix: 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 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.

The final step was to overlay the combined fire layers with the 2022 footprint of the WUI.

Data Source:

- Pyrologix
- WUI (USGS)

File Name: DamagePotential_WUI_2022.tif; DamagePotential_WUI_2022_300m_base.tif; DamagePotential_WUI_2022_30m_normalized.tif; DamagePotential_WUI_2022_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing zero. (1 = low, -1 = high)

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.

FIRE RETURN INTERVAL DEPARTURE (FRID)

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.

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 Region 5 Information Management – Mapping and Remote Sensing (MARS) Team.

Data Source: 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 eVeg 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.

MEAN PERCENT FRI DEPARTURE, SINCE 1908

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: 300m 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:

*[1-(MeanRefFRI/CurrentFRI)]*100* when current FRI is longer than reference FRI (the common condition in most coniferous PFRs)

*-{[1-(CurrentFRI/MeanRefFRI)]}*100* when current FRI is shorter than reference FRI (common in some shrub-dominated PFRs, and areas in the Wildland Urban Interface)

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), Region 5, MARS Team

File Name: meanPFRID_300m.tif; meanPFRID300_normalized.tif

Reference Conditions: The normalized values are rescaled based on percent departure from the mean fire return interval, with emphasis on too infrequent fire as a greater near-term concern, with -1 representing greater than a 67% delinquency in fire frequency compared to the fire return interval, and 1 representing less than a 33% delinquency in fire frequency. (1 = <33%, -1 = >67%)

PROBABILITY OF HIGH FIRE SEVERITY (>8 FT)

Metric Definition and Relevance: This metric represents the probability of high severity fire 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 a certain type of operational control. Mechanical control is generally considered to have a threshold of 8 feet and the probability raster displays the likelihood of exceeding 8-foot heading flame lengths. This data layer was selected to represent a threshold for a high severity fire.

Data Resolution: 300m 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 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.

Probability of High Fire Severity (>8 ft) was developed using WildEST (Wildfire Exposure Simulation Tool). WildEST is 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. For more information on this tool see the source below.

All the WildEST results described thus far above apply to the head of a fire, but a free-burning wildfire spreads in all directions and therefore exhibits a range of flanking and backing behavior in addition to heading behavior.

Flanking and backing fires exhibit a lower spread rate and intensity than at the head of a fire. FSim and other stochastic wildfire simulators inherently capture non-heading fire spread and intensity. The deterministic approach we use in WildEST inherently captures only headfire spread and intensity, so we apply adjustments to headfire intensity based on the geometry of an assumed fire spread ellipse.

Data Source: Pyrologix

File Name: xmechctrl_8_2022_300m.tif; xmechctrl_8_2022_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing zero. (1 = 0%, -1 = 100%)

ANNUAL BURN PROBABILITY

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: 300m 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

File Name: BurnProbability_2022_300m.tif; BurnProbability_2022_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of actual values, with -1 representing low values, and 1 representing high values. (-1 to 1 on observed range [0 – 0.07])

FOREST RESILIENCE

At its most fundamental, forest resilience is the ability of forest vegetation and structure to remain a forest in the face of disturbance (e.g., fire, forest management, climate change, etc.). The Forest Resilience Pillar evaluates forest 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 management, combined with changing climates, have resulted forest structure and composition which are not resilient to contemporary disturbances. Forest structure and composition are one of the few elements of a forest that management can modify through treatments to improve conditions. Comparing contemporary conditions with reference locations that have not been managed and have endured low to moderate severity fire can provide valuable benchmarks for resilient conditions.

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

STRUCTURE

Forest 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, and other land-use practices, the predominant trend across Sierran forests is that they have become denser, with an ingrowth of small, shade-tolerant trees and less structural heterogeneity.

BASAL AREA

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: 300m Raster

Data Units: sq ft/acre

Creation Method: The F3 model generated multiple BA estimates to maximize the potential use by managers. Raster surfaces have been generated for all live trees, live trees by predefined size categories, by tree species, and for snags by predefined size classes.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All 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 30 m 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 (MARS)

File Name: BASATOT_2021_300m_base.tif; BASATOT_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (1 = high, -1 = low)

DENSITY – TREES PER ACRE

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: 300m Raster

Data Units: Live trees/acre

Creation Method: The F3 model generated several raster surfaces of trees per acre as estimates of tree density. This raster surface represents all live trees greater than 1" dbh. . Target 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 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 30 m 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 (MARS)

File Name: TPA_2021_300m_base.tif; TPA_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = low, -1 = high)

DENSITY – LARGE TREES

Metric Definition and Relevance: Large trees are important to forest manager as they have a greater likelihood of survival from fire, provide sources of seed stock and wildlife habitat, and 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 future ones. In consultation with National Forests, "large trees" have been determined as greater than 30" dbh.

Data Resolution: 300m Raster

Data Units: Live trees/acre

Creation Method: The F3 model generated raster surfaces of trees per acre to estimate tree density on the landscape. This raster surface represents all live trees greater than 30" dbh.

2019 to 2021 Update: Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All 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 30 m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate large tree density loss, using the formula:

2021 large tree density = 2019 large tree density – (2019 large tree density * MMI/100)

Although the assumption of direct correlation between canopy cover and large tree density 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 (MARS)

File Name: TPA_30in_up_2021_300m_base.tif; TPA_30in_up_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (-1 = <1st and 1 = >99th percentile across the Sierra Nevada)

ESTIMATED MAXIMUM SDI

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 upper limit to the occupancy of a site, and growth is only possible after the death of some individuals. This upper limit on potential site occupancy has been considered to be species- and site-specific by several authors using different variables to characterize the stand.

Data Resolution: 300m Raster

Data Units: percent

Creation Method: These raster data present the SDI percent of estimated max SDI (Stand Density Index) for the Zeide (1983) calculations (also known as the summation method)).

2019 to 2021 Update: SDI values were adjusted for 2021 following the same procedure as outlined above for density – trees per acre. These adjusted values for actual SDI were used to calculate percentages in combination with the max SDI values from 2019.

Data Source: F3 data outputs (MARS)

File Name: proportion_of_SDI_83_Max_300m.tif; proportion_of_SDI_83_Max_normalized_300m.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing high values, and 1 representing low values. (1 = 0, -1 = 1; max based on observed within climate class)

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 TO SHRUB COVER RATIO

Metric Definition and Relevance: The abundance of different plant life forms provides information about the dominance hierarchy and structural diversity in the ecosystem. The Tree to Shrub Ratio indicates the relative abundance of the two major woody plant types.

Data Resolution: 300m Raster

Data Units: Percent

Creation Method: To model fractional vegetation cover, the CECS DataEngine used existing datasets of vegetation from the Multi-Resolution Land Characteristics Consortium (https://www.mrlc.gov/) to train a machine learning algorithm. These vegetation maps were linked to synthetic reflectance from Landsat to predict the annual tree, shrub, herb, or no vegetation (i.e., barren) cover in each 30m pixel (Wang et al. 2022). For 2021, these predictions were used to calculate the Tree to Shrub Cover Ratio:

[TreeCover/(TreeCover+ShrubCover)]

Locations with < 10% total cover (tree+shrub) were excluded. Resulting fractional values were then multiplied by 100 to express the Tree to Shrub Cover Ratio as a percentage. Thus values > 50% indicate tree dominance and values < 50% indicate shrub dominance.

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

File Name: CECS_TreeToShrubRatio_Pct_300m.tif; Normalized_CECS_TreeToShrubRatio_300m.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = low, 1 = high)

SERAL STAGE

Metric Definition and Relevance: The seral stages 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: 300m Raster

Data Units: Integer, 1 – 3

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

Size Class	Size (inches DBH)	Seral Stage
1 Seedling	< 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 will be lumped into a single classification (24” and up). Late seral stage condition will be evaluated at the HUC12-scale (10,000-30,000 ac) as these patterns can be highly variable at finer-scales. For each HUC12, we calculated the proportion of the watershed that is covered by late seral stage.

Data Source: F3 data outputs (MARS)

File Name: SeralStage_EML_2021_300m.tif; late_SeralStage_prop_300m.tif; late_SeralStage_prop_300m_normalized.tif

Reference Conditions: The late seral stage conditions are a proportion (0 – 1) of the entire HUC12. The normalized late seral stage values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = low, 1 = high)

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.

TREE MORTALITY – PAST 5 YEARS

Metric Definition and Relevance: 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, 2021 Data Products section. This metric represents 2021 status of cumulative tree mortality occurring years 2017-2021. Tree mortality that since its occurrence was affected by fire or land management activities was removed. This metric is provided to complement data (in terms of spatial resolution and canopy cover loss estimates) available from the Region 5’s 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: 300m Raster

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

Creation Method: Dead tree canopy cover fraction change from the eDaRT Mortality Magnitude Index (MMI)

Data Source: Region 5, MARS Team

File Name: Mortality_MMI_2017_2021_300m.tif; Mortality_MMI_2017_2021_normalized_5climateClass300m.tif; Mortality_MMI_2017_2021_compressed.tif; Mortality_MMI_2017_2021_normalized_5climateClass30m.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing high values, and 1 representing low values. (1 = 0%, -1 = 100%; max based on observed values)

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.

CALIFORNIA BLACK OAK STANDS

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: 300m Raster

Data Units: Value, 0 – 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 ACCEL 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_300m.tif;
CA_Black_Oak_Stand_Distribution_2016to2020_300m_normalized.tif;
CA_Black_Oak_Stand_Distribution_2016to2020.tif;
CA_Black_Oak_Stand_Distribution_2016to2020_30m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of the square root of the actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values, and 1 representing high values. (1 = high, -1 = low)

CALIFORNIA SPOTTED OWL

Metric Definition and Relevance: California spotted owl is continuously distributed on the western slope of the Sierra and inhabits elevations ranging from 1,000 to over 7,000 feet, it is a Region 5 Forest Service "Sensitive Species" and a "Management Indicator Species" (representing late seral closed canopy coniferous forest). In November, 2019, the USFWS issued a 12-month finding on a petition to list the California spotted owl under the Endangered Species Act and determined listing to be not warranted at this time (USDI Fish and Wildlife Service 2019). 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 area or activity center. PACs are a USFS land allocation designed to protect and maintain high-quality CSO 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: 300m Raster

Data Units: Continuous, 0 (Low Suitability) to 1 (High Suitability)

Creation Method: CWHR classifications are based on a combination of F3 canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with 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.

The California spotted owl territory suitability metric evaluates the 1000 ac around each 30-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 nesting habitat types. A second data layer to identify locations which meet the criteria for a protected activity center (PAC) [see Operational Data and Resources], which is 300 acres of suitable nesting habitat in a contiguous block has also been developed. Habitat that 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 moderate and high suitability values have been used to create data layers that separately identify suitable nesting and suitable foraging habitat.

Data Source:

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

File Name: CSO_suitablehabitat_combined_300m.tif; CSO_suitablehabitat_combined_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = 0, 1 = 1)

PACIFIC FISHER

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. Suitable habitat is defined by a model developed by US Pacific Southwest Research Station and the Conservation Biology Institute. This metric evaluates the 1000 ac around each 30m pixel to determine if it meets minimum habitat requirements to support a territory.

Data Resolution: 300m Raster

Data Units: Continuous, 0 (Low Suitability) to 1 (High Suitability)

Creation Method: CWHR classifications are based on a combination of F3 canopy cover, F3 size class and vegetation data. The vegetation data integrated the F3 forest type class with 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.

- 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

Data Source:

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

File Name: fisher_suitablehabitat_combined_300m.tif; fisher_suitablehabitat_combined_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = 0, 1 = 1)

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

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: 300m 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 F3 canopy cover, F3 size class, and vegetation data. The vegetation data integrated the F3 forest type class with 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 integrated to represent CWHR habitat attributes – see CWHR section below.

Data Source:

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

File Name: wildlife_species_richness_300m.tif; wildlife_species_richness_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme upper values at the 1^{st} and 99^{th} percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing zero, and 1 representing high values. (-1 = 0 and 1 = >99^{th} percentile across the Sierra Nevada)

THREATENED/ENDANGERED VERTEBRATE SPECIES RICHNESS

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: 300m 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 F3 canopy cover, F3 size class, and vegetation data. The vegetation data integrated the F3 forest type class with 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 integrated to represent CWHR habitat attributes – see CWHR section below.

Data Source:

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

File Name: t_e_species_richness_300m.tif; t_e_species_richness_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = 0, 1 = 1)

COMMUNITY INTEGRITY

Communities of species are the result of a wide array of environmental factors, and these assemblages interact, are interdependent to different degrees, and perform a range of critical ecosystem functions and services. This element reflects community conditions pertaining to species composition and co-occurrence and the implications for performing and maintaining ecosystem functions and services.

HABITAT CONNECTIVITY

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 include 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: 300m 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 ACCEL 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 30m 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: ACCEL_habitatConnectivity_values_300m.tif; ACCEL_habitatConnectivity_values_30m_normalized_5_is_1.tif; ACCEL_habitatConnectivity_values_5_is_1_300m_normalized.tif; ACCEL_habitatConnectivity_valuesInt.tif

Reference Conditions: The normalized values follow the Connectivity Values based on the following logic:

Habitat Connectivity Value	Normalized Value
1	NA
2	-1
3	-0.33
4	0.33
5	1

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.

BIOMASS

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 model, the shrub component has not been included.

Data Resolution: 300m Raster

Data Units: dry weight tons/acre

Creation Method: The F3 model generated several raster surfaces to provide an estimate of the total above ground live tree crown (including foliage) biomass for all trees and of tree stem biomass for trees <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 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 30 m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate biomass volume loss using the formula:

*2021 Biomass Volume = 2019 Biomass Volume – (2019 Biomass Volume * 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).

This layer is derived from MMI adjusted F3 layers (2021) using the following formula: sum(ABGDLVBR, BMSTM_0, BMSTM_2, BMSTM_7)

Data Source: F3 data outputs (MARS)

File Name: AvailableBiomass_2021_300m_base.tif; AvailableBiomass_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (1= high, -1 = low)

COST OF POTENTIAL TREATMENTS

Metric Definition and Relevance: Costs of potential treatments per acre moving sawlogs with a skidder. 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 given 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: 300m Raster

Data Units: dollars

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 have been 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
- ACCEL study area extent (vector): ACCEL study area extent

Data Source: Rocky Mountain Research Station, USFS

File Name: skidder_bio_cost_proj_clip_300m_base.tif; skidder_saw_cost_proj_clip2_300m_base.tif; skidder_bio_cost_proj_clip_300m_normalized.tif; skidder_saw_cost_proj_clip2_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (1= high, -1 = low)

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

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.

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 not measured directly.

TOTAL CARBON

Metric Definition and Relevance: Total Aboveground Carbon is the basis for CARB Natural and Working Lands accounting framework; it also provides context for the other three metrics used to quantify carbon sequestration. For example, instability or lack of resilience in forest 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: 300m Raster

Data Units: Mg C/ha

Creation Method: The Center for Ecosystem Climate Solutions at UC Irvine (CECS) DataEngine model tracks monthly carbon in multiple pools from 1986 to 2021. The carbon components are initialized with eMapR (see References) 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 (Wang et al. 2022) and used to quantitatively transfer or combust pools. The model allocates and turns over material based on allometry scaling theory (Enquist 2002), as adjusted by observational data sets. All aboveground pools (live tree, shrubs and herbs, all dead material) are summed for September of 2021. Specifically, Total Aboveground Biomass was calculated at the end of the October to September Water Year. Native CECS units, calculated in grams of biomass per m^2 were converted to Mg C/ha using the convention of 1 Mg biomass = 0.5 Mg C.

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

File Name: CECS_TotalCarbon_300m.tif; Normalized_CECS_TotalCarbon_300m.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (-1 = <1st and 1 = >99th percentile across the Sierra Nevada)

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 21 tons/acre, Stephens et al., 2022).

LARGE TREE CARBON

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: 300m Raster

Data Units: Mg C/ha

Creation Method: The F3 model generated several different raster surfaces to estimate the stemwood (BMSTM) by predefined size classes and for the branchwood, foliage, and the unmerchantable portion of stemwood above 4" (BMCWN) by the same predefined size classes.

2019 to 2021 Update: Values for each non-overlapping, large tree size class for stemwood (BMSTM) and for branchwood, foliage, and unmerchantable portion of stemwood above 4" (BMCWN) rasters were adjusted for 2021 following the same procedure using eDaRT MMI. The difference between 2019 and 2021 live volume as estimated using MMI percent adjustments, e.g.:

*2021 BMCWN_x = 2019 BMCWN_x – (2019 BMCWN_x * MMI/100)*

And then converted to short tons/acre using a conversion factor of 32.1 cubic feet/ton.

This layer is derived from the adjusted 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 (MARS)

File Name: LargeTreeCarbon_2021_300m_base.tif; LargeTreeCarbon_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (-1 = <1st and 1 = >99th percentile across the Sierra Nevada)

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 mechanistc 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 downstream storage.

ACTUAL EVAPOTRANSPIRATION FRACTION

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 = -2). Such a drought is expected approximately once every 50 years in the Sierra Nevada. The southern Sierra 2012-2015 drought was a SPI-48 drought = -2.0, which resulted in severe vegetation die-off and a marked reduction in water deliveries.

The AETF ranges from 0 to > 100%; a low value indicates a wetter location during drought and a high value indicates a drier location. Locations <100% would be expected to generate runoff, even during a SPI-48 drought = -2.0, and would be expected to continue generating runoff. Locations >100% would be expected to desiccate the soil during drought, with negligible runoff, and increasing vegetation drought stress.

Data Resolution: 300m Raster

Data Units: Percent

Creation Method: The Center for Ecosystem Climate Solutions (CECS) DataEngine uses a simple one bucket model to calculate local (30m pixel) water inputs and outputs. Actual evapotranspiration (AET) is calculated from 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 Water Year (WY) is then divided by the Precipitation that would be calculated for each pixel under a SPI-48 drought = -2.0. This fraction is converted to percent and used as a measure of the local water balance during drought, with the higher values indicating a drier location.

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

File Name: CECS_AETFrac_Pct_300m.tif; Normalized_CECS_AETFrac_300m.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (-1 = <1st and 1 = >99th percentile across the Sierra Nevada)

ANNUAL MEAN RUNOFF

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 ground water flows during a series of years with average precipitation. Larger values indicate more runoff under mean conditions.

Data Resolution: 300m 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 CECS DataEngine uses a simple one bucket model to calculate local (30m pixel) water inputs and outputs.

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. Actual evapotranspiration (AET) is calculated from Landsat observations and eddy covariance, 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. Plant accessible water holding capacity, which is the total amount of soil moisture accessible to the vegetation throughout the full rooting depth, is calculated from the mean observed Dry Season Drawdown. Monthly Precipitation (P) is allocated in the following order: 1) AET, 2) delta regolith moisture, 3) runoff. Hence, runoff occurs when P > AET and the regolith is saturated. The data are calculated based on the canopies observed in the 2021 WY.

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

File Name: CECS_RunoffMean_300m.tif; Normalized_CECS_RunoffMean_300m.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1^{st} and 99^{th} percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing low values and 1 representing high values. (-1 = <1^{st} and 1 = >99^{th} percentile across the Sierra Nevada)

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 SMOKE EMISSIONS – HIGH SEVERITY

Metric Definition and Relevance: These F3- based emissions could be a more locally precise alternative for the standard Landfire/FCCS based estimated emissions for wildfire emissions. Reporting units are not on a per acre, but a per pixel basis, so that zonal summaries for the area of interest can quickly total up the possible emissions, and compare them to Rx fire emissions.

Data Resolution: 300m Raster

Data Units: short tons of PM2.5

Creation Method: This is a first-order estimate (based on FOFEM, or First Order Fire Effects Model, embedded in the FVS Fire and Fuels Extension) generally representing wildfire emissions using standard wildfire conditions (more in the FVS manual). These estimates have been imputed to the landscape by the F3 model and are reported as the metric: Pot_Smoke

2019 to 2021 Update: For areas disturbed 2019-2021 (MMI >=10%), no data is available for year 2021 due to uncertainties in conversions based on the limits with which change detection information for can quantify the individual components of this metric.

Data Source: F3 data outputs (MARS)

File Name: PotentialSmokeHighSeverity_2021_300m_base.tif;
PotentialSmokeHighSeverity_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = <1st and -1 = >99th percentile across the Sierra Nevada)

POTENTIAL SMOKE EMISSIONS – MODERATE SEVERITY

Metric Definition and Relevance: In California, and for prescribed fires, the PFIRS system requires emission estimates alongside fuels (biomass) estimates. PFIRS emission estimates directly inform the modeled results that are disseminated by the smoke spotter app (and in the PFIRS system). F3- based emissions could be a more locally precise alternative for the standard Landfire/FCCS based emissions for Rx fire projects currently implemented in

PFIRS. Reporting units are not on a per acre, but a per pixel basis, so that zonal summaries for the area of interest can quickly total up the possible emissions, and compare them to wildfire emissions.

Data Resolution: 300m Raster

Data Units: short tons PM2.5

Creation Method: This is a first order estimate (based on FOFEM, or First Order Fire Effects Model, algorithms embedded in FVS) generally representing moderate fire behavior generally observed during Rx Fire or periods when/where fire would be managed for resource objective during wildfire events. These estimates have been imputed to the landscape by the F3 model and are reported as the metric: Pot_Smok_1

2019 to 2021 Update: For areas disturbed 2019-2021 (MMI >=10%), no data is available for year 2021 due to uncertainties in conversions based on the limits with which change detection information for can quantify the individual components of this metric.

Data Source: F3 data outputs (MARS)

File Name: PotentialSmokeModerateSeverity_2021_300m_base.tif; PotentialSmokeModerateSeverity_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = <1st and -1 = >99th percentile across the Sierra Nevada)

WETLAND INTEGRITY

Wetlands provide critical habitat, store carbon, enhance water quality, control erosion, filter and retain nutrient pollution, and provide spaces for recreation. Meadow and riparian ecosystems provide ecosystem services and are key linkages between upland and aquatic systems in forested landscapes.

DESIRED OUTCOME: Meadow and riparian ecosystems provide multiple ecosystem services and are 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

Metric Definition and Relevance: Sensitivity is 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: 300m 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:

- Data Basin – SierraNV_Meadow_ClimateVulnerability_vSep2019.shp
- Center for Watershed Sciences, UC Davis – see Meadows

File Name: Meadow_SensNDWI_2019_300m_base.tif; Meadow_SensNDWI_2019_300m_normalized.tif; Meadow_SensNDWI_2019_30m_compressed.tif; Meadow_SensNDWI_2019_30m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing zero. (1 = 0, -1 = 1)

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 JUSTICE

Environmental Justice 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.

LOW-INCOME POPULATIONS

Metric Definition and Relevance: This data layer, updated May 2022, reflects low-income community designations. Certain populations are especially vulnerable to the impacts of climate change. At least 35 percent of California Climate Investments must benefit these populations, which include disadvantaged communities, low-income communities, and low-income households, also known as "priority populations."

Low-income communities and households are defined as the census tracts and households, respectively, that are either at or below 80 percent of the statewide median income, or at or below the threshold designated as low-income by the California Department of Housing and Community Development's (HCD) Revised 2021 State Income Limits (Low-income definitions per Assembly Bill (AB) 1550 (Gomez, Chapter 369, Statutes of 2016)).

Data Resolution: 300m Raster

Data Units: binary; 1 = Yes, 2 = No

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.

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0

File Name: LowIncome_CCI_2021_300m_base.tif; LowIncome_CCI_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of potential values, with -1 representing low values, and 1 representing high values. (-1 = 0, 1 = 1)

HOUSING BURDEN PERCENTILE

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: 300m 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_300m_base.tif; HousingBurdenPctl_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = low, -1 = high)

UNEMPLOYMENT PERCENTILE

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: 300m and/or 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. See page 193 in the document link above.

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0

File Name: UnemploymentPctl_2021_300m_base.tif; UnemploymentPctl_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on nearly the full range of actual values, with the most extreme values truncated at the 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. (1 = low, -1 = high)

OPERATIONAL DATA AND RESOURCES

In addition to the metric data layers assembled for this ACCEL 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, POD delineations), 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). We have provided data layers specific to Meadows and the California Wildlife Habitat Relationships within this designation of operational data.

MEADOWS

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. 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 – https://meadows.ucdavis.edu/resources/36

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

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 ACCEL project.

Data Resolution: 30m Raster

Data Units: Thematic

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 ACCEL project area, it was decided to fill NoData areas with land cover types from the National Land cover Dataset (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.

Data Source:

- Forest type designation from Forest Vegetation Simulator (FVS) F3 data outputs (MARS); 2021
- National Land Cover Dataset (NLCD); 2019
- USDA Forest Service, CALVEG Existing Vegetation (MARS); 2016
- Ecosystem Disturbance and Recovery tracker (eDaRT) Mortality Magnitude Index (MMI) (MARS); 2021

CWHR – SIZE CLASS

Metric Definition and Relevance: breakdown of stands by WHR diameter size class

Data Resolution: 30m Raster

Data Units: Thematic

Creation Method: The F3 model will be used to generate raster surfaces for trees per acre by CWHR diameter size class as well as the average height for live trees by CWHR diameter size class.

- 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) as described in the Density – Trees Per Acre section above.

Data Source: F3 data outputs (MARS)

CWHR – DENSITY BY CANOPY COVER

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 before thinning
- 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 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 30 m pixel over that time period. The resulting value was subtracted from 2019 canopy cover to give 2021 canopy cover. It should be noted that the same MMI-based adjustment was used for both CPYCOVR and STANDCC rasters. Because CPYCOVR is not corrected for crown overlap, the use of a loss estimate that is an absolute proportion per 30 m pixel may result in underestimates for 2021 CPYCOVR in some cases.

This canopy cover value 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.

Data Source: F3 data outputs (MARS)

DATA DISCLAIMERS

Appropriate use includes regional assessments of vegetation cover, land cover, or land use change trends, total extent of vegetation cover, land cover, or land use change, and aggregated summaries of vegetation cover, land cover, or land use change. Further use includes applying these data to assess management opportunities for treatments to restore landscape resiliency.

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CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE (CDFW)

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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 FOREST OBSERVATORY (SALO SCIENCES)

Effective date: September 8th, 2020

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.

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CALIFORNIA OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT (OEHHA)

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CENTER FOR ECOSYSTEM CLIMATE SOLUTIONS (CECS) – UC IRVINE

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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.

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.

USDA FOREST SERVICE

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 land 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.

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Additional information on California Department of Fish and Wildlife Areas of Conservation Emphasis program: https://wildlife.ca.gov/Data/Analysis/Ace

Additional information on California Office of Environmental Health Hazard Assessment CalEnviroScreen 4.0 report: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

Additional information on Forest Vegetation Simulator: https://www.fs.usda.gov/fvs/index.shtml

Additional information on Monitoring Trends in Burn Severity (MTBS) program: https://www.mtbs.gov/

Additional information on Multi-Resolution Land Characteristics Consortium (MRLC): https://www.mrlc.gov/

Additional information on Oregon State University Environmental Monitoring, Analysis, and Process Recognition (eMapR) Lab: http://emapr.ceoas.oregonstate.edu/

Additional information on Oregon State University PRISM Climate Group: https://prism.oregonstate.edu/

Additional information on Rapid Assessment of Vegetation Condition after Wildfire (RAVG): https://burnseverity.cr.usgs.gov/ravg/

Essential FVS User's Guide: https://www.fs.usda.gov/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf

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