ACCEL METRIC DICTIONARY

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TABLE OF CONTENTS

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.

In addition to metrics being described in term of actual values, most have also been 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 though there are some exceptions regarding 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.

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

GENERAL F3 PROCESS

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

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

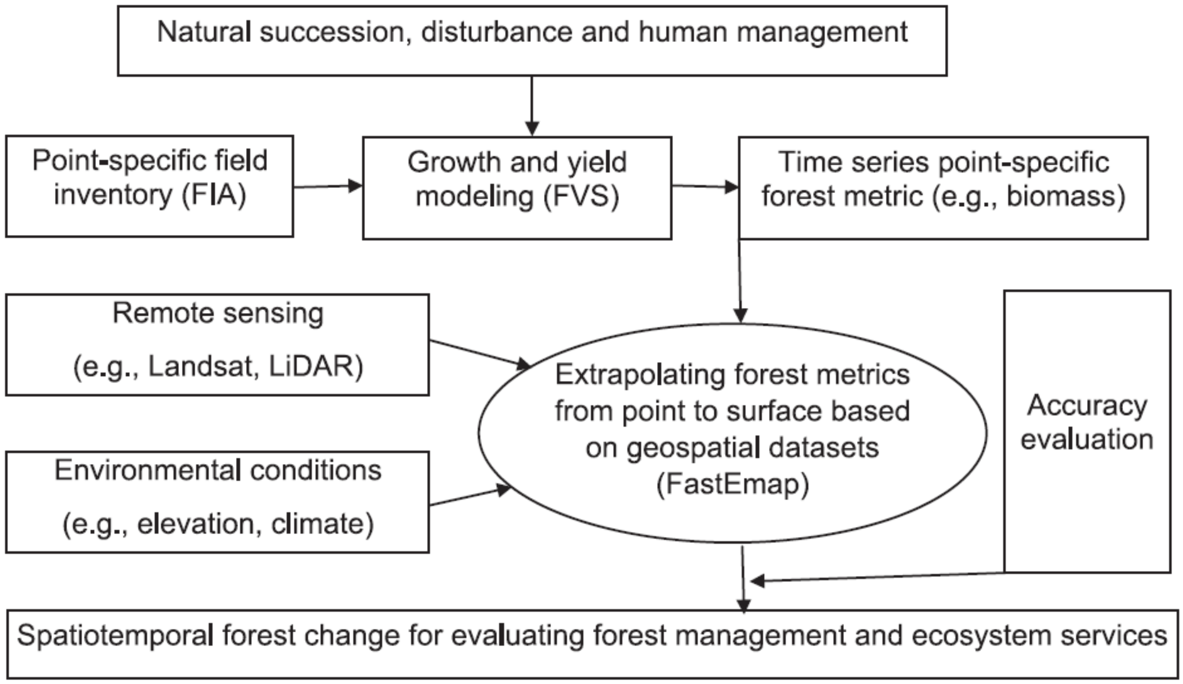

Fig. 1. Flowchart of F^3 modeling framework.

ADVANTAGES AND LIMITATIONS

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

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

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: 30m and 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 Pyrologix that integrates spatially continuous weather input variables, weighted based on how they will likely be realized on the landscape. This makes the deterministic intensity values developed with WildEST more robust for use in effects analysis than the stochastic intensity values developed with FSim. This is especially true in low wildfire occurrence areas where predicted intensity values from FSim are reliant on a very small sample size of potential weather variables. It also allows for more appropriate weighting of high-spread conditions into fire behavior calculations. WildEST also produces indices of conditional and expected ember production from vegetated areas (pixels) and load to other pixels in the analysis area. Please reference the Pyrologix 2021 project report (Volger et al., 2021) for more information on WildEST analysis.

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

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_30m_normalized.tif; StructureExposureScore_WUI_2022_300m_base.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 zero. This interpretation reflects the assumption that lower exposure is more favorable.

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: 30m and 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 Pyrologix: conditional risk to potential structures (cRPS) and conditional ember load index (cELI).

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

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

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

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

cELI is also calculated in WildEST, and represents the relative ember load per pixel, given that a fire occurs, based on surface and canopy fuel characteristics, climate, and topography within the pixel. Units are 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, LLC
- WUI (USGS)

File Name: DamagePotential_WUI_2022.tif; DamagePotential_WUI_2022_30m_normalized.tif; DamagePotential_WUI_2022_300m_base.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. This interpretation reflects the assumption that lower damage potential is more favorable.

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

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 existing vegetation map (USDA Forest Service, Mapping and Remote Sensing Team) for California from the year 2011, with the vegetation typing ("CALVEG") grouped into 28 pre-settlement fire regime (PFR) types, as defined by Van de Water and Safford (2011). The 2011 eVeg map is used as the baseline for all subsequent FRID maps to freeze the underlying vegetation template and permit temporal comparisons without introducing vegetation type change as a confounding factor.

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: 30m and 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:

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

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

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

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

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

Data Source:

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

File Name: meanPFRID.tif; meanPFRID_30m_normalized.tif; meanPFRID_300m.tif; meanPFRID_300m_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. This interpretation reflects concerns for fire being too infrequent, with delinquency greater than 1/3 of the average fire return interval considered to be more favorable than longer periods of delinquency. We did not create a commensurate reference condition for too frequent fire, but it could be done using the same general premise.

MEAN PERCENT FRI DEPARTURE, SINCE 1970

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

Data Resolution: 30m and 300mRaster

Data Units: Percent

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

Data Source:

- Fire History (2022), CAL FIRE

- Existing Vegetation (CALVEG), Region 5, MARS Team

File Name: meanPFRID_1970.tif; meanPFRID_1970_normalized.tif; meanPFRID_1970_300m.tif; meanPFRID_1970_300m_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. This interpretation reflects concerns for fire being too infrequent, with delinquency greater than 1/3 of the average fire return interval considered to be more favorable than longer periods of delinquency. We did not create a commensurate reference condition for too frequent fire, but it could be done using the same general premise.

MEAN FRI CONDITION CLASS

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

Data Resolution: 30m and 300m Raster

Data Units: Integer, -3 to 3

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

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

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

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

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

Data Source:

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

File Name: meanCC_FRI.tif; meanCC_FRI_normalized.tif; meanCC_FRI_freq_rescale_30m.tif; meanCC_FRI_infreq_rescale_30m.tif; meanCC_FRI_300m.tif; meanCC_FRI_300m_normalized.tif

Reference Conditions: The normalized values are rescaled as a one tailed evaluation based on condition classes. When too infrequent fire is a greater near-term concern, -1 = CC(3) (greater than a 67% delinquency), and 1 = CC(1) or lower (less than a 33% delinquency in fire frequency). When too frequent fire is a greater near-term concern, -1 = CC(-3) (greater than a 67% overage), and 1 = greater than CC(-1) (less than a or lower (less than a 33% overage). This interpretation reflects concerns for fire being too infrequent, with delinquency greater than 1/3 of the average fire return interval considered to be more favorable than longer periods of delinquency. We did not create a commensurate reference condition for too frequent fire, but it could be done using the same general premise.

TIME SINCE LAST FIRE

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

Data Resolution: 30m and 300m Raster

Data Units: Years

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

Data Source:

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

File Name: TSLF.tif; TSLF_30m_normalized.tif; TSLF_300m.tif; TSLF_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the comparison of TSLF to the mean fire return interval (FRI; from the FRID map) for a given location. The formula for the comparison depends on if the TSLF is greater or less than the mean reference FRI (meanRefFRI).

- If the TSLF > meanRefFRI, then *(TSLF/meanRefFRI-1)*100*. This will result in a positive percent value.
- If the TSLF < meanRefFRI, then *TSLF/meanRefFRI*-1*100*. This will result in a negative percent value.

These percentages are then normalized using the following thresholds to reflect the degree to which fire is too infrequent:

- 1 is assigned to all values < 33% (including all negative percentages)
- -1 is assigned to all values >67%
- Values between 33% and 67% will range from -1 to 1 in a linear manner.

This interpretation reflects concerns for fire being too infrequent, with delinquency greater than 1/3 of the average fire return interval considered to be more favorable than longer periods of delinquency. We did not create a commensurate reference condition for too frequent fire, but it could be done using the same general premise.

RECENT FIRE SEVERITY

Metric Definition and Relevance: Fire severity classification (low, moderate, high) that burned within the last 10 years (2012-2021).

Data Resolution: 30m and 300m Raster

Data Units: Value, 1 to 3

Creation Method: The difference-adjusted relativized difference normalized burn ratio (RdNBR) was calculated using methods modified from Parks et al (2018). Fire perimeters were obtained from CAL FIRE's April 2022 fire perimeter database. A function for estimating basal area loss from RdNBR values was fit to data from Miller et al (2009) using quasibinomial logistic regression and applied to the 2012-2021 fires. Estimated basal area loss was thresholded to represent low (< 25% loss), moderate (25% – 75% loss), and high (> 75% loss) burn severity. For areas where multiple sequential fires burned from 2012-2021 the maximum burn severity is reported.

- 1: Low Severity
- 2: Moderate Severity
- 3: High Severity

Data Source:

- Landsat 8, NASA
- Fire History (2022), CAL FIRE
- Postfire mortality data, Miller et al. 2009

File Name: fire_severity_class_max_2012to2021.tif; fire_severity_class_max_2012to2021_300m.tif; fire_severity_class_max_2012to2021_30m_normalized.tif; fire_severity_class_max_2012to2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the three values assigned to areas with recent fire, which reflects concern for high severity fire: 1 = low, 0 = moderate, -1 = high. Areas with no recent fire are assigned N/A. This interpretation reflects concerns about high severity fire, with less high severity fire being more favorable.

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: 30m and 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, LLC

File Name: BurnProbability_2022.tif; BurnProbability_2022_30m_normalized.tif; BurnProbability_2022_300m_base.tif; BurnProbability_2022_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of actual values, with -1 representing high values, and 1 representing low values. This interpretation reflects concerns for the occurrence of unplanned fire, so lower probabilities are considered more favorable.

PROBABILITY OF FIRE SEVERITY (LOW, MODERATE, HIGH)

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

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

Data Resolution: 30m and 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.

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

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

$$1 - xmanualctrl\_4$$

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

$$xmanualctrl\_4 - xmechctrl\_8$$

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

Data Source: Pyrologix, LLC

File Name: probLowSevFire_2022.tif; probLowSevFire_2022_30m_normalized.tif; probLowSevFire_2022_300m.tif; probLowSevFire_2022_300m_normalized.tif; probModSevFire_2022.tif; probModSevFire_2022_300m.tif; xmechctrl_8_2022_30m.tif; xmechctrl_8_2022_30m_normalized.tif; 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.

- For the high severity layer, -1 represents high values and 1 represents low values. This interpretation reflects concerns about high severity fire, with lower probabilities considered more favorable.
- For the low severity layer, 1 represents high values and -1 represents low values. This interpretation reflects desire for low severity fire, with higher probabilities considered more favorable.
- No normalized rescaling was performed for the moderate severity layer.

SEVERITY

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

TOTAL DEAD/DOWN FUELS

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

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

Data Resolution: 30m and 300m Raster

Data Units: Short tons/acre

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

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

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

$$sum(FLOAD\_1\text{-}9, LITTER, DUFF)$$

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

File Name: TotalFuelLoad_2021_30m.tif; TotalFuelLoad_2021_30m_normalized.tif; TotalFuelLoad_2021_300m.tif; TotalFuelLoad_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the full range of actual values, with -1 representing high values and 1 representing low values. This interpretation reflects concerns about high fuel levels posing a fire risk, with lower fuel levels considered more favorable.

STANDING DEAD AND LADDER FUELS

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

Data Resolution: 30m and 300m Raster

Data Units: Short tons/acre

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

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

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

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

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

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

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

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

File Name: StdDeadLadFuels_2021_30m.tif; StdDeadLadFuels_2021_30m_normalized.tif; StdDeadLadFuels_2021_300m.tif; StdDeadLadFuels_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. This interpretation reflects concerns about high fuel levels posing a fire risk, with lower fuel levels considered more favorable.

TOTAL FUEL EXPOSED TO FIRE

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

Data Resolution: 30m and 300m Raster

Data Units: Short tons/acre

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

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

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

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

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

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

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

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

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

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

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

File Name: TotFuelExpFire_2021_30m.tif; TotFuelExpFire_2021_30m_normalized.tif; TotFuelExpFire_2021_300m.tif; TotFuelExpFire_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. This interpretation reflects concerns about high fuel levels posing a fire risk, with lower fuel levels considered more favorable.

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.

NATURAL CONIFER REGENERATION PROBABILITY

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

Data Resolution: 30m and 300m Raster

Data Units: Probability, 0 to 1

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

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

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

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

- Postfire mortality data, Miller et al. 2009

Data Source: Department of Plant Sciences, UC Davis

File Name: most_recent_postfire_conifer_regen_prob_2012to2021.tif; most_recent_postfire_conifer_regen_prob_2012to2021_30m_normalized.tif; most_recent_postfire_conifer_regen_prob_2012to2021_300m.tif; most_recent_postfire_conifer_regen_prob_2012to2021_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. This interpretation reflects concerns for lack of natural regeneration, with higher probabilities of natural regeneration considered more favorable.

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: 30m and 300m Raster

Data Units: Sq ft/acre

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

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

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

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

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

File Name: BASATOT_2021_30m.tif; BASATOT_2021_30m_normalized.tif; 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. This interpretation reflects the desire to restore the representation of large trees on the landscape, so higher biomass values considered more favorable.

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: 30m and 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 on the landscape. This raster surface represents all live trees greater than 1" dbh (TPA). Reference conditions can be generated from contemporary reference sites for mature forest conditions outside of the WUI.

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

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

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

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

File Name: TPA_2021_30m.tif; TPA_2021_30m_normalized.tif; 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 1^{st} and 99^{th} percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values and 1 representing low values. This interpretation reflects concerns about high tree densities increasing drought vulnerability, with lower tree densities considered more favorable.

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: 30m and 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 on the landscape. These raster surfaces were generated in predefined non-overlapping size categories (TPA_x), and this raster surface represents all live trees 30" dbh and greater.

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

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

Although the assumption of direct correlation between canopy cover and 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). The assumption that canopy cover loss, as estimated using eDaRT MMI, was equitably distributed among the predefined size classes may result in over- or under-estimates of actual tree density per individual size class, depending on location.

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

$$sum(TPA\_35, TPA\_40)$$

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

File Name: TPA_30in_up_2021_30m.tif; TPA_30in_up_2021_30m_normalized.tif; 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. This interpretation reflects concerns about reductions in large tree densities, with higher large tree densities considered more favorable.

DENSITY – SNAGS

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

Data Resolution: 30m and 300m Raster

Data Units: Standing dead trees/acre

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

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

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

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

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

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

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

File Name: SNG_25_2021_30m.tif; SNG_25_2021_30m_normalized.tif; SNG_25_2021_300m_base.tif; SNG_25_2021_300m_normalized.tif; SNG_35_2021_30m.tif; SNG_35_2021_30m_normalized.tif; SNG_35_2021_300m_base.tif; SNG_35_2021_300m_normalized.tif; SNG_40_2021_30m.tif; SNG_40_2021_30m_normalized.tif; SNG_40_2021_300m_base.tif; SNG_40_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. This interpretation reflects concerns about low snag densities, with higher snag densities considered more favorable.

STAND DENSITY INDEX

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

Data Resolution: 30m Raster

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

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

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

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

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

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

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

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

File Name: SDI_33_2021_30m.tif; SDI_33_2021_300m.tif; SDI_83_2021_30m.tif; SDI_83_2021_300m.tif

PROPORTION OF 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 approximate upper limit to the SDI of a site, and tree growth may be limited by competition as SDI approaches maximum SDI. This approximate upper limit on potential site SDI has been considered to be species- and site-specific by several authors using different variables to characterize the stand.

Data Resolution: 30m and 300m Raster

Data Units: Proportion, 0 to 1

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

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

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

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

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

The maximum SDI was calculated as the 99th percentile of observed values for each of five broad climate classes (see operational data layers section). Then for each pixel, the proportion of maximum SDI is simply calculated as SDI divided by maximum SDI:

$$Proportion\_MaxSDI = SDI/MaxSDI$$

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

File Name: proportion_of_SDI_33_Max_30m.tif; proportion_of_SDI_33_Max_normalized_30m.tif; proportion_of_SDI_33_Max_300m.tif; proportion_of_SDI_33_Max_normalized_300m.tif; proportion_of_SDI_83_Max_30m.tif; proportion_of_SDI_83_Max_normalized_30m.tif; 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. This interpretation reflects concerns over high tree densities exceeding site carrying capacities leading to increased drought vulnerability and competition-induced mortality, with lower proportions of maxSDI values considered more favorable.

QUADRATIC MEAN DIAMETER

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

Data Resolution: 30m and 300m Raster

Data Units: Inches

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

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

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

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

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

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

File Name: QMD_TOT_2021_30m.tif; QMD_TOT_2021_300m.tif

CANOPY COVER

Metric Definition and Relevance: Canopy cover is the percentage "of forest floor covered by the vertical projection of the tree crowns." Cover is measured vertically with a very narrow angle of view that approaches a point and indicates how much of the forest floor is vertically overtopped with canopy. Canopy cover is often cited as an important habitat feature for a number of sensitive species associated with old-forest conditions in the Sierra Nevada and is used in determining California Wildlife Habitat Relationship (CWHR) habitat types.

Data Resolution: 30m and 300m Raster

Data Units: Percent

Creation Method: The F3 model generated several different raster surfaces of percent canopy cover estimates; by predefined tree size categories and for all live trees (>=0.1" DBH). It is important for users to understand the subtle difference between the two total canopy cover percent value raster surfaces:

- CPYCOVR = canopy percent cover based on stockable area for all live trees
- STANDCC = canopy percent cover (corrected for crown overlap) based on stockable area for all live trees

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

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

It should be noted that the same eDaRT MMI-based adjustment was used for CPYCOVR and STANDCC. Because CPYCOVR is not corrected for crown overlap, the use of a loss estimate that is an absolute proportion per 30m pixel (i.e., the eDaRT MMI) may result in over- or underestimates for 2021 CPYCOVR, depending on location.

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

File Name: CPYCOVR_2021_30m.tif; CPYCOVR_2021_30m_normalized.tif; CPYCOVR_2021_300m.tif; CPYCOVR_2021_300m_normalized.tif; STANDCC_2021_30m.tif; STANDCC_2021_30m_normalized.tif; STANDCC_2021_300m.tif; STANDCC_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. This interpretation simply reflects the range of values, without any particular value for open versus closed conditions.

FINE-SCALE HETEROGENEITY

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

FINE-SCALE HETEROGENEITY INDEX

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

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

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

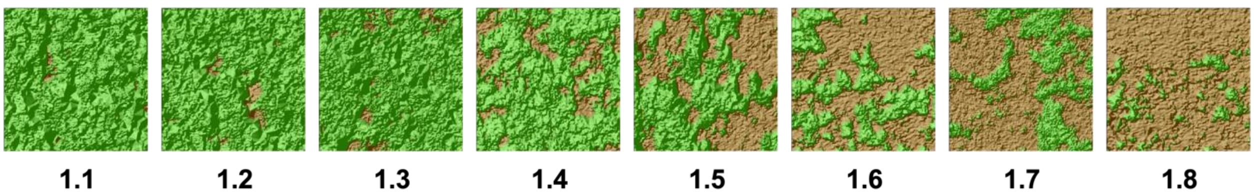

Image courtesy of Jonathan T. Kane, University of Washington.

Data Resolution: 30m and 300m Raster

Data Units: Fractal dimension index, 1 to 2

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

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

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

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

File Name: fractal_dim_spring_2020_30m.tif; fractal_dim_spring_2020_30m_normalized.tif; fractal_dim_spring_2020_300m.tif; fractal_dim_spring_2020_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the 20th and 80th percentile of actual values, with -1 representing low values, and 1 representing high values. This interpretation reflects concerns for conditions that are overly homogeneous but in either direction (too closed or too open), with more heterogeneous conditions considered more favorable.

PERCENT CANOPY COVER

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

Data Resolution: 30m and 300m Raster

Data Units: Percent

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

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

File Name: perc_canopy_cover_spring_2020_30m.tif; perc_canopy_cover_spring_2020_30m_normalized.tif; perc_canopy_cover_spring_2020_300m.tif; perc_canopy_cover_spring_2020_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the 20^{th} and 80^{th} percentile of actual values, with -1 representing low values, and 1 representing high values. This interpretation simply reflects the range of values, without any particular value for open versus closed conditions.

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: 30m and 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_30m.tif; Normalized_CECS_TreeToShrubRatio_30m.tif; 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. This interpretation reflects concerns over tree cover loss, with higher tree cover values considered more favorable.

SERAL STAGE

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

Data Resolution: 30m and 300m Raster

Data Units: Integer, 1 to 3

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

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

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

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

File Name: SeralStage_EML_2021.tif; SeralStage_EML_2021_300m.tif; early_SeralStage_prop.tif; early_SeralStage_prop_30m_normalized.tif; early_SeralStage_prop_300m.tif; early_SeralStage_prop_300m_normalized.tif; late_SeralStage_prop.tif; late_SeralStage_prop_30m_normalized.tif; late_SeralStage_prop_300m.tif; late_SeralStage_prop_300m_normalized.tif

Reference Conditions: Early seral stage conditions are a proportion (0 – 1) of the entire HUC12. The normalized early seral stage values are rescaled based on the full range of potential values, with -1 representing high values and 1 representing low values. This interpretation reflects concerns over conversion of large areas of mature forest to early forest, with lower values considered more favorable.

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. This interpretation reflects concerns over loss of late seral conditions, with higher values considered more favorable.

DISTURBANCE

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

TIME SINCE LAST DISTURBANCE

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

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

Data Resolution: 30m and 300m Raster

Data Units: Years

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

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

File Name: TSD_2021.tif; TSD_2021_30m_normalized.tif; TSD_2021_300m.tif; TSD_2021_300m_normalized.tif

Reference Conditions: The normalized values are rescaled based on the comparison of time since last disturbance to the mean fire return interval (FRI) for a given location. The formula for the comparison depends on if the time since last disturbance (TSLD) is greater or less than the mean FRI.

- If the TSLD > FRI, then (1-TSLD/FRI1)*100. This will result in a positive percent value.
- If the TSLD < FRI, then -1*TSLD/FRI*100. This will result in a negative percent value.

These percentages are then normalized using the following thresholds to reflect the degree to which disturbance is too infrequent:

- 1 is assigned to all values < 33% (including all negative percentages)
- -1 is assigned to all values >67%
- Values between 33% and 67% will range from -1 to 1 in a linear manner

This interpretation reflects concerns for disturbance being too infrequent, with delinquency greater than 1/3 of the average time since last disturbance interval considered to be more favorable than longer periods of delinquency. We did not create a commensurate reference condition for too frequent disturbance, but it could be done using the same general premise.

TREE MORTALITY – PAST 5 YEARS AND PAST 1 YEAR

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

Data Resolution: 30m and 300m Raster

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

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

Data Source: Region 5, MARS Team

File Name: Mortality_MMI_2017_2021.tif; Mortality_MMI_2017_2021_normalized_5climateClass30m.tif; Mortality_MMI_2017_2021_300m.tif; Mortality_MMI_2017_2021_normalized_5climateClass300m.tif; Mortality_MMI_2021.tif; Mortality_MMI_2021_30m_normalized.tif; Mortality_MMI_2021_300m.tif; Mortality_MMI_2021_300m_normalized.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. This interpretation reflects concern for widespread tree mortality, with lower values considered more favorable.

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.

AMERICAN/PACIFIC MARTEN

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

Data Resolution: 30m and 300m Raster

Data Units: Resolution dependent

- 30m data – Binary, 0/1
- 300m data – Continuous, 0 (Low Suitability) to 1 (High Suitability)

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

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

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

Data Source:

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

File Name: marten_suitablehabitat.tif; marten_suitablehabitat_30m_normalized.tif; marten_suitablehabitat_300m.tif; marten_suitablehabitat_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. This interpretation reflects concern for the persistence of this species, with higher habitat values considered more favorable.

BAND-TAILED PIGEON

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

Data Resolution: 30m and 300m Raster

Data Units: Binary, 0/1

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

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

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

File Name: band_tailed_pigeon_250ac_binary.tif; band_tailed_pigeon_250ac_binary_30m_normalized.tif; band_tailed_pigeon_250ac_binary_300m.tif; band_tailed_pigeon_250ac_binary_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. This interpretation reflects concern for the persistence of this species, with higher habitat values considered more favorable.

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: 30m and 300m Raster

Data Units: Value, 0 to 1000

Creation Method: Statistical models were fit to seasonal median Landsat 8 spectral bands 1 – 7 for the period encompassing 2016 – 2020. Training occurrence data spanned the Sierra Nevada 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_30m.tif; CA_Black_Oak_Stand_Distribution_2016to2020_30m_normalized.tif; CA_Black_Oak_Stand_Distribution_2016to2020_300m.tif; CA_Black_Oak_Stand_Distribution_2016to2020_300m_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. This interpretation reflects concern for the geographic extent and overall abundance of this species, with higher likelihood values considered more favorable.

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 California spotted owl nesting and roosting habitat around active sites. Territorial owls typically defend a geographic area consistently used for nesting, roosting, and foraging, containing essential habitat for survival and reproduction. The USDA Forest Service calls for an area of 1,000 acres in the central Sierra Nevada around core use areas, including the associated protected activity center, with a minimum of 400 acres of suitable habitat.

Data Resolution: 30m and 300m Raster

Data Units: Resolution dependent

- 30m data – Binary, 0/1
- 300m data – Continuous, 0 (Low Suitability) to 1 (High Suitability)

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

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

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

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

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

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

Data Source:

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

File Name: CSO_suitablehabitat_combined.tif; CSO_suitablehabitat_combined_30m_normalized.tif; CSO_suitablehabitat_combined_300m.tif; CSO_suitablehabitat_combined_300m_normalized.tif; CSO_territory.tif; CSO_territory_30m_normalized.tif; CSO_territory_300m.tif; CSO_territory_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. This interpretation reflects concern for the persistence of this species, with higher habitat values considered more favorable.

GIANT SEQUOIA STANDS

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

Data Resolution: Vector, polygon; 30m and 300m raster

Data Units: Resolution dependent

- Vector – Tabular attributes
- Raster – Binary, 0/1

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

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

Sequoia Tree Inventory (STI) dataset dictated the boundary shape. Elsewhere, the Observed Tree Inventory (OTI) points guided the boundary formation.

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

Data Source: Region 5, MARS Team

File Name: SEGI_MU_2022_92_1.shp; SEGI_MU_2022_92_1.tif; SEGI_MU_2022_92_1_30m_normalized.tif; SEGI_MU_2022_92_1_300m.tif; SEGI_MU_2022_92_1_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. This interpretation reflects concern for the persistence of this species, with greater extent considered more favorable.

NORTHERN GOSHAWK

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

Data Resolution: 30m and 300m Raster

Data Units: Resolution dependent

- 30m data – Binary, 0/1
- 300m data – Continuous, 0 (Low Suitability) to 1 (High Suitability)

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

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

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

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

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

Data Source:

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

File Name: ng_suitablehabitat_combined.tif; ng_suitablehabitat_combined_30m_normalized.tif; ng_suitablehabitat_combined_300m.tif; ng_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. This interpretation reflects concern for the persistence of this species, with higher habitat values considered more favorable.

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.

Data Resolution: 30m and 300m Raster

Data Units: Resolution dependent

- 30m data – Binary, 0/1
- 300m data – Continuous, 0 (Low Suitability) to 1 (High Suitability)

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

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

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

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

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

Data Source:

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

File Name: fisher_suitablehabitat_combined.tif; fisher_suitablehabitat_combined_30m_normalized.tif; 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. This interpretation reflects concern for the persistence of this species, with higher habitat values considered more favorable.

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

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

Data Source:

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

File Name: wildlife_species_richness.tif; wildlife_species_richness_30m_normalized.tif; 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 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing zero, and 1 representing high values. This interpretation reflects concern for declines in species diversity as a function of richness, with richness values considered more favorable.

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

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

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

Data Source:

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

File Name: t_e_species_richness.tif; t_e_species_richness_30m_normalized.tif; 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. This interpretation reflects concern for the persistence of these species, with higher richness values considered areas more valuable for species conservation efforts.

BETA DIVERSITY

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

Data Resolution: 30m and 300m Raster

Data Units: Sørensen index, 0 to 1

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

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

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

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

Data Source:

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

File Name: beta_diversity_30m.tif; beta_diversity_30m_normalized.tif; beta_diversity_300m.tif; beta_diversity_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. This interpretation reflects concern for the conservation of species diversity, with higher beta diversity considered to be areas with greater conservation value.

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.

FUNCTIONAL GROUP SPECIES RICHNESS

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

Data Resolution: 30m and 300m Raster

Data Units: Number of species

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

Data Source:

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

File Name: cavity_nesters_excavators_species_richness.tif; cavity_nesters_excavators_species_richness_30m_normalized.tif; cavity_nesters_excavators_species_richness_300m.tif; cavity_nesters_excavators_species_richness_300m_normalized.tif; herbivores_species_richness.tif; herbivores_species_richness_30m_normalized.tif; herbivores_species_richness_300m.tif; herbivores_species_richness_300m_normalized.tif; insectivores_species_richness.tif; insectivores_species_richness_30m_normalized.tif; insectivores_species_richness_300m.tif; insectivores_species_richness_300m_normalized.tif; predators_species_richness.tif; predators_species_richness_30m_normalized.tif; predators_species_richness_300m.tif; predators_species_richness_300m_normalized.tif; seed_spore_dispersers_species_richness.tif; seed_spore_dispersers_species_richness_30m_normalized.tif; seed_spore_dispersers_species_richness_300m.tif; seed_spore_dispersers_species_richness_300m_normalized.tif; soil_aerators_species_richness.tif;

soil_aerators_species_richness_30m_normalized.tif; soil_aerators_species_richness_300m.tif; soil_aerators_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 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing zero, and 1 representing high values. This interpretation reflects concern for the conservation of functional diversity, with higher diversity considered to be areas with greater conservation value.

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: 30m and 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 30 m pixel) which has then been binned into four classifications:

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

Data Source:

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

File Name: ACCEL_habitatConnectivity_values.tif; ACCEL_habitatConnectivity_values_30m_normalized_5_is_1.tif; ACCEL_habitatConnectivity_values_300m.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 relationships between degree of landscape connectedness, with higher values indicating increasingly important corridors/connectors.

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.

SAWTIMBER

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

Data Resolution: 30m and 300m Raster

Data Units: Dry weight tons/acre

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

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

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

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

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

File Name: ABGDLVSM_2021_30m.tif; ABGDLVSM_2021_30m_normalized.tif; ABGDLVSM_2021_300m.tif; ABGDLVSM_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. This interpretation reflects the desire to understand sawlog availability and potential yields, with higher values considered more favorable.

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 F3 model, the shrub component has not been included.

Data Resolution: 30m and 300m Raster

Data Units: Dry weight tons/acre

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

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

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

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

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

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

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

File Name: AvailableBiomass_2021.tif; AvailableBiomass_2021_30m_normalized.tif; 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. This interpretation reflects the desire to understand biomass availability and potential yields, with higher values considered more favorable.

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: 30m and 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 will be performed:

1. Subset and attribute OSM roads with speed based on criteria in Table 1.
2. Create barrier to offroad motion for off road analysis using a subset of OSM streams, water bodies, interstates, and highways.
3. Estimate potential on road and offroad cost surfaces for each harvesting system using interactive sliders based on the criteria in Table 2.
4. Create felling and processing surfaces and add potential costs.
5. Specify where harvesting systems occur and subset system costs to those locations.
6. Create final spatial representation of the potential cost to treat each raster cell on a dollar per CCF basis.
7. Save final raster surfaces.

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

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

Data Source: Rocky Mountain Research Station

File Name: skidder_bio_cost_proj_clip.tif ; skidder_bio_cost_proj_clip_30m_normalized.tif; skidder_bio_cost_proj_clip_300m_base.tif; skidder_bio_cost_proj_clip_300m_normalized.tif; skidder_saw_cost_proj_clip2.tif; skidder_saw_cost_proj_clip2_30m_normalized.tif; skidder_saw_cost_proj_clip2_300m_base.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 higher costs and 1 representing lower costs. This interpretation reflects the desire to consider costs in project design, with lower costs considered more favorable.

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.

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

CARBON STORAGE

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

TOTAL CARBON (CECS)

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

Data Resolution: 30m and 300m Raster

Data Units: Mg C/ha

Creation Method: The Center for Ecosystem Climate Solutions (CECS) DataEngine model tracks monthly carbon in multiple pools from 1986 to 2021. The carbon components are initialized with eMapR (see Additional Resources) observations for the early Landsat era; the model then runs freely based on Landsat and other observations. Disturbances and disturbance intensity are tracked annually by Landsat (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_30m.tif; Normalized_CECS_TotalCarbon_30m.tif; 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 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. This interpretation reflects the desire for increased carbon sequestration on natural and working lands, with higher values considered more favorable.

TOTAL CARBON (F3)

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

Data Resolution: 30m and 300m Raster

Data Units: Mg C/ha

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

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

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

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

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

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

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

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

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

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

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

File Name: F3_TotalCarbon_2021_30m.tif; F3_TotalCarbon_2021_30m_normalized.tif; F3_TotalCarbon_2021_300m.tif; F3_TotalCarbon_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. This interpretation reflects the desire for increased carbon sequestration on natural and working lands, with higher values considered more favorable.

ABOVEGROUND LIVE TREE CARBON (F3)

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

Data Resolution: 30m and 300m Raster

Data Units: Mg C/ha

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

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

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

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

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

$$[Abovegroun]*2.2417023114334]$$

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

File Name: F3_AbovegroundLiveTreeCarbon_2021.tif; F3_AbovegroundLiveTreeCarbon_2021_30m_normalized.tif; F3_AbovegroundLiveTreeCarbon_2021_300m.tif; F3_AbovegroundLiveTreeCarbon_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. This interpretation reflects the desire for increased carbon sequestration on natural and working lands, with higher values considered more favorable.

CARBON STABILITY

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

LARGE TREE CARBON

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

Data Resolution: 30m and 300m Raster

Data Units: Mg C/ha

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

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

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

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

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

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

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

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

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

File Name: LargeTreeCarbon_2021.tif; LargeTreeCarbon_2021_30m_normalized.tif; 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. This interpretation reflects the desire for increased stable carbon sequestration, with higher values considered more favorable.

DEAD CARBON

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

Data Resolution: 30m and 300m Raster

Data Units: Mg C/ha

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

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

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

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

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

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

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

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

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

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

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

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

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

File Name: DeadCarbon_2021.tif; DeadCarbon_2021_30m_normalized.tif; DeadCarbon_2021_300m.tif**;** DeadCarbon_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. This interpretation reflects the desire for increased carbon sequestration, with higher values considered more favorable. However, live carbon is more desirable (stable) than dead carbon, and dead carbon has negative consequences in terms of fuels and fire dynamics (see the Fire Dynamics pillar).

WATER SECURITY

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

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

QUANTITY

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

ACTUAL EVAPOTRANSPIRATION 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: 30m and 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_30m.tif; Normalized_CECS_AETFrac_30m.tif; 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 high values and 1 representing low values. This interpretation reflects concerns for drought vulnerability and water availability for non-forest processes, with low values considered more favorable.

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: 30m and 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_30m.tif; Normalized_CECS_RunoffMean_30m.tif; 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 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. This interpretation reflects concerns for water availability in support of processes and uses outside of the forest ecosystem, with higher values being considered more favorable.

REDUCTION IN RUNOFF DURING EXTREME DROUGHT

Metric Definition and Relevance: By definition, drought reduces the supply of water. However, the impact of this reduction varies across the landscape and is directly influenced by vegetative demand. The Reduction in Runoff During Extreme Drought indicates the potential reduction in surplus water during a drought. Extreme drought is defined as a 48-month period where the Standardized Precipitation Index (SPI, NCAR 2022) is 2.5 standard deviations below the long-term mean (SPI-48 = -2.5). Larger values indicate more severe reductions.

Data Resolution: 30m and 300m Raster

Data Units: mm/y

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. The DataEngine calculates runoff during an extreme drought in mm/y as described above with the Precipitation input defined by 2.5 standard deviations less than the 30-yr Normal Precipitation. The Reduction in Runoff During Extreme Drought is calculated:

$$\textit{Annual Mean Runoff (mm/y)} - \textit{Runoff During an Extreme Drought (mm/y)}$$

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

File Name: CECS_ReductionRunoffDrought_30m.tif; Normalized_CECS_ReductionRunoffDrought_30m.tif; CECS_ReductionRunoffDrought_300m.tif; Normalized_CECS_ReductionRunoffDrought_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 high values and 1 representing low values. This interpretation reflects concern for plant drought vulnerability in extreme drought conditions, with lower reductions considered more favorable.

VEGETATIVE STRESS DURING EXTREME DROUGHT

Metric Definition and Relevance: Vegetation stress is a measure of the moisture shortfall in a given year. It is an effective early predictor of potential drought-induced tree mortality (Madakumbura et al. 2020). Shortfall is the difference between plant demand (i.e., actual evapotranspiration) and water supply (i.e., precipitation and soil moisture). Vegetative Stress During Extreme Drought indicates the unmet water demand during an extreme drought, defined as a 48-month period where the Standardized Precipitation Index (SPI, NCAR 2022) is 2.5 standard deviations below the long-term mean (SPI-48 = -2.5). More negative values indicate more stress.

Data Resolution: 30m and 300m Raster

Data Units: mm/y

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. 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. The unmet water demand under extreme drought conditions (SPI-48 = -2.5) is calculated:

$$(Precipitation + Soil\ Moisture\ Availability) - AET$$

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

File Name: CECS_VegStressDrought_30m.tif; Normalized_CECS_VegStressDrought_30m.tif; CECS_VegStressDrought_300m.tif; Normalized_CECS_VegStressDrought_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. This interpretation reflects concerns for vegetation loss to drought stress, with lower values considered more favorable.

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: The F3 modeled-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: 30m and 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, algorithms 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: No adjustments were made for 2021 due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), no data is represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that the estimation did not change significantly over the course of two years.

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

File Name: PotentialSmokeHighSeverity_2021.tif; PotentialSmokeHighSeverity_2021_30m_normalized.tif; 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 1^{st} and 99^{th} percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing high values, and 1 representing low values. This interpretation reflects concerns for poor air quality affecting human health and recreation opportunities, with lower emissions considered more favorable.

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). The F3 model-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: 30m and 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 the FVS Fire and Fuels Extension) generally representing moderate fire behavior which is 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: No adjustments were made for 2021 due to uncertainties in conversions based on the limits with which change detection information can quantify the individual components of this metric. For areas with disturbance 2019-2021 (defined as eDaRT MMI >= 10% canopy cover loss), no data is represented for 2021 (i.e., NULL). For areas undisturbed 2019-2021, it is a reasonable assumption that the estimation did not change significantly over the course of two years.

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

File Name: PotentialSmokeModerateSeverity_2021.tif;
PotentialSmokeModerateSeverity_2021_30m_normalized.tif;
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. This interpretation reflects concerns for poor air quality affecting human health and recreation opportunities, with lower emissions considered more favorable.

TOTAL FUEL LOAD

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

HEAVY FUELS

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

Data Resolution: 30m and 300m Raster

Data Units: Short tons biomass/acre

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

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

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

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

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

File Name: HeavyFuels_2021_30m.tif; HeavyFuels_2021_30m_normalized.tif; HeavyFuels_2021_300m_base.tif; HeavyFuels_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. This interpretation reflects concerns for the relationship between fuels and expected emissions from fire, with lower values considered more favorable.

WETLAND INTEGRITY

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

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

HYDROLOGIC FUNCTION

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

MEADOW SENSITIVITY INDEX

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: 30m and 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: Center for Watershed Sciences, UC Davis – see Meadows

File Name: Meadow_SensNDWI_2019_30m.tif; Meadow_SensNDWI_2019_30m_normalized.tif; Meadow_SensNDWI_2019_300m_base.tif; Meadow_SensNDWI_2019_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. This interpretation reflects concerns for impacts to meadow function and integrity from drought and climate impacts, with lower sensitivity considered more favorable.

COMPOSITION

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

AQUATIC SPECIES RICHNESS

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

Data Resolution: 30m and 300m Raster

Data Units: Count

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

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

Data Source:

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

File Name: aquatic_species_richness.tif; aquatic_species_richness_30m_normalized.tif; aquatic_species_richness_300m.tif; aquatic_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 1st and 99th percentile to reduce the influence of outliers on the expressed range of normalized values, with -1 representing zero, and 1 representing high values. This interpretation reflects concerns for conserving aquatic species diversity, with greater richness considered more favorable.

WETLAND TYPE COMPOSITION

Metric Definition and Relevance:

- *Wetlands* - This data set represents the extent, approximate location, and type of wetlands and deepwater habitats in the ACCEL boundary for the Sierra Nevada. These data delineate the areal extent of wetlands and surface waters as defined by Cowardin et al. (1979).
- *Riparian* - This data set represents the extent, approximate location, and type of riparian habitats in the ACCEL boundary extent. These data delineate the areal extent of riparian habitats as defined by A System for Mapping Riparian Areas in the United States (USFWS, 2009)

Data Resolution: Vector, polygon

Data Units: Thematic

Creation Method: Downloaded from the National Wetlands Inventory (NWI), see metadata for creation methods.

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

File Name: ACCEL_wetlands; ACCEL_riparian

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.

RACE ETHNICITY – NATIVE AMERICAN POPULATIONS

Metric Definition and Relevance: The Race/Ethnicity metrics are derived from 2020 Decennial Census Redistricting File data published by the Census Bureau in September 2021. This metric identifies group block areas (Block Groups (BGs) are statistical divisions of census tracts, generally defined to contain between 600 and 3,000 people) where Native Americans are disproportionately present in comparison to the total Native American population of the ACCEL project region. The relative concentration of Native Americans individuals in a block group is expressed categorically.

Data Resolution: 30m and 300m Raster

Data Units: Categorical

Creation Method: Dr. Mark Adams from the Forest Service Office of Climate and Sustainability worked with the 2021 Census data to glean the Race/Ethnicity features from the 2020 Decennial Census Redistricting File and 2021 US Census Tiger Files for block groups. Working at the block group level, the demographic metrics to identify locations where Native Americans live were pulled. To provide flexibility in how these indicators could be used, three descriptive options were provided:

- Concentration Metric – a numeric value describing the relative concentration tendency
- Concentration Class – alphabetic string describing a range of values centered on relation to the numeric value of 1 (e.g., "high")
- Ordinal two-digit string code alternative to the concentration class field with the following interpretation

Class name	Class code	Interpretation
Zero or nearly none	00	The proportion of the subject population within the block group feature of interest is roughly 10% or less of the proportion of the subject population in the total ACCEL region: e.g., if 25% of people in the ACCEL region are Hispanic or Latino, only 2.5% or less are Hispanic in the block group with these field values
Low	01	Roughly 10 to 50% of the corresponding subject population proportion
Somewhat low	02	Roughly 50 to 85%
Proportionate	03	Roughly 85 to 115%
Somewhat high	04	Roughly 115 to 150%

High	05	Roughly 150 to 200%
Very high	06	Roughly 200 to 300%
Extremely high	07	The proportion of the subject population within the block group feature of interest is more than 300% (3 times) the corresponding subject population proportion in the total ACCEL region: e.g., if 25% of the people in the ACCEL region are Hispanic or Latino, then 75% or more of the people in the block group with these field values are Hispanic/Latino

All data are from Table P2 ("Hispanic or Latino, and not Hispanic or Latino by Race") of the 2020 Public Law 94-171 Redistricting Summary File released by the Census Bureau in fall 2021. The TIGER/Line vector polygons attributed as NHSNATIVEAMERICAN_20_CLASS (Not Hispanic, Native American alone: Concentration classification) have been converted to 30m raster. The raster was then binned and reclassed into 4 categories on the field name (NHSPNATIVE) following the categories from the original dataset:

- Low/Somewhat Low/Proportionate/Somewhat High/
- High
- Very High
- Extremely High

Data Source: Dr. Mark Adams (Office of Climate and Sustainability, U.S. Forest Service) – Table P2 of the 2020 Public Law 94-171 Redistricting Summary File released by the Census Bureau in fall 2021

File Name: RaceEthnicity_NonHispNatAmerican_2020.tif; RaceEthnicity_NonHispNatAmerican_2020_30m_normalized.tif; RaceEthnicity_NonHispNatAmerican_2020_300m.tif; RaceEthnicity_NonHispNatAmerican_2020_300m_normalized.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. This interpretation reflects concerns for projects to benefit Native American populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no Native American populations (higher values).

RACE ETHNICITY – HISPANIC POPULATIONS

Metric Definition and Relevance: The Race/Ethnicity metrics are derived from 2020 Decennial Census Redistricting File data published by the Census Bureau in September 2021. This metric identifies group block areas (Block Groups (BGs) are statistical divisions of census tracts, generally defined to contain between 600 and 3,000 people) where Hispanic/Latino are disproportionately present in comparison to the total Hispanic/Latino population of the ACCEL project region. The relative concentration of Hispanic/Latino individuals is expressed categorically.

Data Resolution: 30m and 300m Raster

Data Units: Categorical

Creation Method: Dr. Mark Adams from the Forest Service Office of Climate and Sustainability worked with the 2021 Census data to glean the Race/Ethnicity features from the 2020 Decennial Census Redistricting File and 2021 US Census Tiger Files for block groups. Working at the block group level, the demographic metrics to identify locations where Hispanic/Latino people live were pulled. To provide flexibility in how these indicators could be used, three descriptive options were provided:

- Concentration Metric – a numeric value describing the relative concentration tendency
- Concentration Class – alphabetic string describing a range of values centered on relation to the numeric value of 1 (e.g., “high”)
- Ordinal two-digit string code alternative to the concentration class field with the following interpretation

Class name	Class code	Interpretation
Zero or nearly none	00	The proportion of the subject population within the block group feature of interest is roughly 10% or less of the proportion of the subject population in the total ACCEL region: e.g., if 25% of people in the ACCEL region are Hispanic or Latino, only 2.5% or less are Hispanic in the block group with these field values
Low	01	Roughly 10 to 50% of the corresponding subject population proportion
Somewhat low	02	Roughly 50 to 85%
Proportionate	03	Roughly 85 to 115%
Somewhat high	04	Roughly 115 to 150%
High	05	Roughly 150 to 200%
Very high	06	Roughly 200 to 300%
Extremely high	07	The proportion of the subject population within the block group feature of interest is more than 300% (3 times) the corresponding subject population proportion in the total ACCEL region: e.g., if 25% of the people in the ACCEL region are Hispanic or Latino, then 75% or more of the people in the block group with these field values are Hispanic/Latino

All data are from Table P2 (“Hispanic or Latino, and not Hispanic or Latino by Race”) of the 2020 Public Law 94-171 Redistricting Summary File released by the Census Bureau in fall 2021. The TIGER/Line vector polygons attributed as HISPANICPOC_20_CLASS (Hispanic and/or person of color: Concentration classification) have been converted to 30m raster. The raster was then binned and reclassed into 4 categories on the field name (HISPANICPO) following the categories from the original dataset:

- Low/Somewhat Low/Proportionate/Somewhat High/
- High
- Very High
- Extremely High

Data Source: Dr. Mark Adams (Office of Climate and Sustainability, U.S. Forest Service) – Table P2 of the 2020 Public Law 94-171 Redistricting Summary File released by the Census Bureau in fall 2021

File Name: RaceEthnicity_HispanicPOC_2020.tif; RaceEthnicity_HispanicPOC_2020_30m_normalized.tif; RaceEthnicity_HispanicPOC_2020_300m.tif; RaceEthnicity_HispanicPOC_2020_300m_normalized.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. This interpretation reflects concerns for projects to benefit Hispanic/Latino populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no Hispanic/Latino populations (higher values).

LOW-INCOME POPULATIONS – PROPORTIONAL

Metric Definition and Relevance: The Low-Income metric is derived from American Community Survey data published by the Census Bureau. The ACS is administered on a rolling basis to a small annual sample of households: samples for the estimate of low-income population and total population in households with income estimated used for this feature were collected from 2016 to 2020. Thus, the concentration of low-income individuals does not describe a point in time, as do the race/ethnicity counts. This metric identifies group block areas (Block Groups (BGs) are statistical divisions of census tracts, generally defined to contain between 600 and 3,000 people) where individuals living in low-income households are disproportionately present in comparison to the total households population of the ACCEL project region. The relative concentration of low-income individuals is expressed categorically.

Data Resolution: 30m and 300m Raster

Data Units: Categorical

Creation Method: Dr. Mark Adams from the Forest Service Office of Climate and Sustainability worked with the 2021 Census data to glean the Income Levels features from the US Census Tiger Files. The low-income features include a single metric describing the tendency of people living in households with income less than twice the federal poverty threshold that applies to their household type, relative to all people living in households for which income is estimated. These data are from the American Community Survey (ACS) and are estimates. The full range of the 90% confidence interval around these estimates is provided so that users can assess the unreliability of estimates for individual block groups: in general, the more rural the block group, the worse the estimate.

Class name	Class code	Interpretation
Zero or nearly none	00	The proportion of the subject population within the block group feature of interest is roughly 10% or less of the proportion of the subject population in the total ACCEL region: e.g., if 25% of people in the ACCEL region are Hispanic or Latino, only 2.5% or less are Hispanic in the block group with these field values
Low	01	Roughly 10 to 50% of the corresponding subject population proportion
Somewhat low	02	Roughly 50 to 85%
Proportionate	03	Roughly 85 to 115%
Somewhat high	04	Roughly 115 to 150%
High	05	Roughly 150 to 200%
Very high	06	Roughly 200 to 300%
Extremely high	07	The proportion of the subject population within the block group feature of interest is more than 300% (3 times) the corresponding subject population proportion in the total ACCEL region: e.g., if 25% of the people in the ACCEL region are Hispanic or Latino, then 75% or more of the people in the block group with these field values are Hispanic/Latino

In its application to generating public engagement opportunity maps, the category class field can be visualized as a cold-to-hot color ramp. There is also a "proportionate" value, indicating that a block group is similar to the overall region's population characteristics. In the low income and other ACS data maps, unclassifiable records – usually 10-15% of all block groups in the mapped region – are grayed out.

All data are from Table P2 ("Hispanic or Latino, and not Hispanic or Latino by Race") of the 2020 Public Law 94-171 Redistricting Summary File released by the Census Bureau in fall 2021. A spatial subset of the Census Bureau's 2020 TIGER/Line polygon block group features data was received from Mark Adams: *ACCEL_LowIncome_2020ACS_5YR_PartBlockGroup* – a nominal category describing probable degree of concentration of individuals with low income (households with income less than twice the federal poverty threshold). The TIGER/Line vector polygons attributed as INCL200PCTPOV_CLASS (individuals with low income [< 200% poverty]: Concentration classification) have been converted to 30m raster. The raster was then binned and reclassed into 4 categories on the field name (NCL200PCT) following the categories from the original dataset:

- Unclassifiable
- Somewhat High/Low/Somewhat Low/Proportionate/Zero or Nearly None
- High
- Very High
- Extremely High

Data Source: Dr. Mark Adams (Office of Climate and Sustainability, U.S. Forest Service) – Table C17002 of the 2020 American Community Survey 5-Year Estimates released by the Census Bureau in spring 2022

File Name: LowIncome200pctPov_2020.tif; LowIncome200pctPov_2020_30m_normalized.tif; LowIncome200pctPov_2020_300m.tif; LowIncome200pctPov_2020_300m_normalized.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. This interpretation reflects concerns for projects to benefit low-income populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no low-income populations (higher values).

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: 30m and 300m Raster

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

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.tif; LowIncome_CCI_2021_30m_normalized.tif; LowIncome_CCI_2021_300m.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 high values, and 1 representing low values. This interpretation reflects concerns for projects to benefit low-income populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no low-income populations (higher values).

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: 30m and 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_30m.tif; HousingBurdenPctl_2021_30m_normalized.tif; 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. This interpretation reflects concerns for projects to benefit economically stressed populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no economically stressed populations (higher values).

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: 30m and 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. Unlike the decennial census, which attempts to survey the entire population and collects a limited amount of information, the ACS releases results annually based on a sub-sample of the population and includes more detailed information on socioeconomic factors such as unemployment. Multiple years of data are pooled together to provide more reliable estimates for geographic areas with small population sizes. The most recent results available at the census tract level are the 5-year estimates for 2015-2019. The data are made available using the U.S. Census data download website.

Data Source: California Environmental Protection Agency, CalEnviroScreen 4.0

File Name: UnemploymentPctl_2021_30m.tif; UnemploymentPctl_2021_30m_normalized.tif; 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. This interpretation reflects concerns for projects to benefit economically stressed populations, with areas of higher densities considered to benefit more from investments (lower values) than areas with limited or no economically stressed populations (higher values).

OPERATIONAL DATA LAYERS

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). These data are provided to assist managers in putting proposed treatments into context for what is feasible and what might constrain project planning.

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

ADMINISTRATIVE

BUILDING STRUCTURE DENSITY

Definition and Relevance: Microsoft Maps is releasing computer generated building footprints. This ACCEL dataset is a subset of the original covering the entire United States.

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method: Microsoft building footprints from Bing Imagery; noise and suspicious data removed, such as false positives from the predictions, then apply a polygonization algorithm to detect building edges and angles to create a proper building footprint

Data Source: Microsoft; Building Footprints - Bing Maps (microsoft.com)

File Name: building_footprints.shp

HIGH-USE RECREATION AREAS

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

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

The Trail_QAQC feature class contains data for all existing, planned and decommissioned trails. It contains detailed dates and strategies for every possible mode of travel that could be used on terra, snow or water trails.

Data Resolution: Vector, Points and Lines

Data Units: Tabular attributes

Creation Method: see Metadata

Data Source: USFS Enterprise Data Warehouse (EDW)

File Name: RecSites, RecOpps, Trail_QAQC

LAND DESIGNATIONS

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

Data Resolution: Vector, polygon

Data Units: Tabular attributes

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

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

Data Source: USFS Enterprise Data Warehouse (EDW)

File Name: Wilderness; USFS_Inventory_Roadless_Areas_SN; WildScenicRiver

OWNERSHIP

Definition and Relevance: Ownership is a commonly used base layer used in a wide range of business functions and these data are intended to provide a depiction of the land ownership within the ACCEL project area.

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method:

- NFS lands: *Basic Ownership* – an area depicted as surface ownership parcels dissolved on the same ownership classification.

- Non-FS lands: *ownership20_1* – Includes lands owned by each federal agency, state agency, local government entities, conservation organizations, and special districts. It does not include lands of private ownership.

Data Source: NFS and CAL FIRE

File Name: BasicOwnership; ownership20_1

ROADS

Definition and Relevance: The National Forest System (NFS) roads which have been designated as open to motorized vehicles under the Travel Management Rule are included in the feature class. Routes not designated for motor use (such as non-motorized trails, single-purpose trails, single-purpose roads and trails) have not been included.

The USGS Transportation downloadable data from The National Map (TNM) is based on TIGER/Line data provided through U.S. Census Bureau.

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method:

- NFS Lands pulled from the Enterprise Data Warehouse; Motor Vehicle Use (MVUM) and filtered to Operational Maintenance Level 2-5 within the ACCEL boundary.
- The National Map (TNM) - Road Segment feature class subsetted to the ACCEL boundary.

Data Source: USFS Enterprise Data Warehouse (EDW)and USGS, The National Map (TNM)

File Name: FS_roads_OperLvl2_5; TNM_RoadSegment_ACCEL

TERRESTRIAL

FOREST TYPE

Definition and Relevance: Managers work with forest types for a variety of purposes and knowing the major forest type of a target location helps to assess the best suited treatment for the site.

Data Resolution: 30m Raster

Data Units: FIA Forest Type Code

Creation Method: The F3 model relies on FVS to classify an FIA plot to a forest or vegetation type. The assigned forest or vegetation type is then imputed across the project area. Appendix B from the Essential FVS User's guide provides a complete list of FIA forest types (https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf). The following is the list of FIA Forest Types within the ACCEL project area:

FIA Code	Forest Type
183	Western Juniper
184	Juniper Woodland
185	Pinyon Juniper Woodland
221	Ponderosa Pine

222	Incense-cedar
224	Sugar Pine
241	Western White Pine
261	White Fir
262	Red Fir
270	Mountain Hemlock
281	Lodgepole Pine
342	Giant Sequoia
361	Knobcone Pine
365	Foxtail Pine / Bristlecone Pine
366	Limber Pine
367	Whitebark Pine
371	California Mixed Conifer
703	Cottonwood
901	Aspen
911	Red Alder
912	Bigleaf Maple
921	Gray Pine
922	California Black Oak
923	Oregon White Oak
924	Blue Oak
925	Deciduous Oak Woodland
931	Coast Live Oak
932	Canyon Live Oak / Interior Live Oak
941	Tanoak
942	California Laurel
951	Pacific Madrone
953	Mountain Brush Woodland
997	FVS Other Hardwoods
999	Non-stocked

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

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

It should be noted that the same MMI-based adjustment was used for CPYCOVR and STANDCC (corrected for crown overlap) which are based on stockable area for all live trees. For areas where 2021 STANDCC values dropped below 10%, the forest type code was changed to 999 (non-stocked).

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

File Name: Total3Run_FORTYPE_NoMGT_2021_V20220512.tif

PROTECTED ACTIVITY CENTERS (PAC)

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

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Description: The CSO PAC and the Northern goshawk's PAC is 300 acres of suitable nesting habitat in a contiguous block.

Creation Method: Downloaded from USFS NRM using the Geospatial Interface (GI)

Data Source: USFS_NRIS_FAUNA for Natural Resource Manager (NRM) Wildlife

File Name: SNV_All_PACS_20220301

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: Numeric (see crosswalk below)

Creation Method: This dataset was initially cross-walked to CWHR from the F3 model of forest type ("FORTYPE") and then updated to 2021, with disturbance changes from the eDaRT Mortality Magnitude Index (MMI). Since the F3 algorithm only models trees, to create a complete wall-to-wall dataset necessary to create biodiversity layers for the ACCEL project area, it was decided to fill NoData areas with land cover types from the National Land Cover Database (NLCD). To differentiate NLCD's generalized "Deciduous Forest", "Evergreen Forest", "Mixed Forest", and "Shrub/Scrub", the CALVEG Existing Vegetation (eVeg) was used to identify vegetation types in greater detail.

Value	CWHR_Type	Habitat Type
100	JUN	Tree
200	PJN	Tree
300	PPN	Tree

400	SMC	Tree
500	SCN	Tree
600	WFR	Tree
700	RFR	Tree
800	LPN	Tree
900	RDW	Tree
1000	CPC	Tree
1100	VRI	Tree
1200	ASP	Tree
1300	MRI	Tree
1400	BOP	Tree
1500	MHW	Tree
1600	BOW	Tree
1700	ASC	Shrub
1800	URB	Urban
1900	DSW	Shrub
2000	DSC	Shrub
2100	AGS	Shrub
2200	BAR	Non_Vegetated
2300	CRP	Developed_Habitats
2400	MCH	Shrub
2500	BBR	Shrub
2600	SGB	Shrub
2700	DRI	Tree
2800	LAC	Water
2900	WTM	Herbaceous
3000	MCP	Shrub
3100	JPN	Tree
3200	EPN	Tree
3300	MHC	Tree
3400	LSG	Shrub
3500	PGS	Herbaceous
3600	FEW	Herbaceous
3700	ADS	Shrub
3800	RIV	Water
3900	DOR	Developed_Habitats
4000	PAS	Herbaceous
4100	JST	Tree
4200	CRC	Shrub
4400	VOW	Tree
4900	DFR	Tree

Data Source:

- Forest type designation from Forest Vegetation Simulator (FVS); F3 data outputs, Region 5, MARS Team; 2021
- National Land Cover Database (NLCD); 2019
- Existing Vegetation (CALVEG), Region 5, MARS Team; 2016
- Ecosystem Disturbance and Recovery tracker (eDaRT) Mortality Magnitude Index (MMI), Region 5, MARS Team; 2021

File Name: f3veg100_NLCD_Integer.tif

CWHR – SIZE CLASS

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

Data Resolution: 30m Raster

Data Units: Tabular attributes

Creation Method: The F3 model generated raster surfaces for trees per acre by predefined non-overlapping CWHR diameter size class (Class 1 – 5).

- Size Class 0: "X" (non-forest)
- Size Class 1: Seedling (dbh is less than 1")
- Size Class 2: Sapling (dbh 1" to 6")
- Size Class 3: Pole tree (dbh 6" to 11")
- Size Class 4: Small tree (dbh 11" to 24")
- Size Class 5: Medium to large tree (dbh > 24")
- Size Class 6: Multi-layered trees of size class 5 over smaller trees of size class 3 or 4

2019 to 2022 Update: Tree density values for 2021 were adjusted independently for each CWHR diameter size class (Class 1 – 5). Values for 2021 were adjusted using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The MMI value for canopy cover loss was used as a direct proxy to estimate TPA loss, using the formula:

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

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

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

File Name: Total3Run_SZ_NoMGT_2021_V20220512.tif

CWHR – DENSITY BY CANOPY COVER

Metric Definition and Relevance: the breakdown of stand density by WHR size class

Data Resolution: 30m Raster

Data Units: Thematic

Creation Method: The F3 model uses FVS to generate raster surface estimates of percent canopy cover of all live trees (>=0.1 inch dbh). There is a subtle difference between the two canopy cover rasters produced by F3:

- CPYCOVR = canopy percent cover based on stockable area for all live trees
- STANDCC = canopy percent cover (corrected for crown overlap) based on stockable area for all live trees

2019 to 2022 Update: The raster surface values were adjusted to 2021 using the Ecosystem Disturbance and Recovery Tracker (eDaRT), described in the Introduction. All eDaRT events beginning August 1, 2019 through November 30, 2021 were identified, and the corresponding Mortality Magnitude Index (MMI) values for these events was summed, giving the estimated fractional canopy cover loss per 30m pixel over that time period. The resulting value was subtracted from 2019 canopy cover to give 2021 canopy cover.

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

It should be noted that the same eDaRT MMI-based adjustment was used for CPYCOVR and STANDCC. Because CPYCOVR is not corrected for crown overlap, the use of a loss estimate that is an absolute proportion per 30m pixel (i.e., the eDaRT MMI) may result in over- or underestimates for 2021 CPYCOVR, depending on location.

The adjusted canopy cover value from STANDCC has been binned according to the California Wildlife Habitat Relationships (CWHR) canopy closure categories*:

- Value 0 = < 10% Not determined/not applicable canopy (X)
- Value 1= 10.0-24.9% Sparse canopy (S)
- Value 2= 25.0-39.9% Open canopy (P)
- Value 3= 40.0-59.9% Moderate canopy (M)
- Value 4= > 60.0 Dense canopy(D)

*NOTE: There is an acknowledged difference between canopy closure and canopy cover. Canopy closure is a measure of the percentage of the sky hemisphere obscured by vegetation over a point, as opposed to canopy cover, the measure of canopy porosity averaged over a stand. The CWHR canopy crown closure percent categories have been used to classify the calculated Forest Canopy Cover data. Closure provides valuable information about the understory light, microclimate, and microhabitat environment at a specific location. See PSW-GTR-237 for more details.

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

File Name: Total3Run_STANDCC_NoMGT_2021_V20220512.tif

AQUATIC

LAKES/PONDS

Definition and Relevance: Waterbodies such as lake/pond features are represented in NHDWaterbody. They portray the spatial geometry and the attributes of the feature. These water polygons may have NHDFlowline artificial paths drawn through them to allow the representation of water flow direction. Other NHDWaterbody features are swamp/marsh, reservoir, playa, estuary, and ice mass. These data were used to erase areas of lakes and ponds from every raster metric in the ACCEL project dataset.

Data Resolution: 30m and 300m Raster

Data Units: Binary, 0/1

Creation Method: This dataset is a subset of vector polygon NHD waterbodies, encompassing the ACCEL project boundary and converted to a raster grid at 30m and 300m resolutions based on existence/non-existence.

Data Source: USGS National Hydrography Dataset (NHD); https://www.usgs.gov/national-hydrography/national-hydrography-dataset

File Name: accel_nhd_lakes_mask_30m_v3_output.tif; accel_nhd_lakes_mask_300m_v3_output.tif

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. In version 2, existing polygons were split, reduced in size, or merged, and additional polygons not captured were digitized. If split, the Original ID was maintained in one half and a new ID created for the other half. When adjacent meadows were merged, only one ID was retained and the unused ID was "decommissioned." Newly digitized meadows were assigned a new sequential ID.

Version 3 – Polygons for the entire Sierra National Forest (SNF) were replaced by more accurate data received from the GIS staff on the SNF. As in version 2, if a meadow was split the original ID from version 2 was retained for one half and a new sequential ID created for the other half if greater than 1 acre. Unused IDs were "decommissioned."

Data Source: Center for Watershed Sciences, UC Davis

File Name: Sierra_Nevada_MultiSource_Meadow_Polygons_Compilation_v3

PERENNIAL, INTERMITTENT AND EPHEMERAL STREAMS

Definition and Relevance: USGS National Hydrography Dataset (NHD); Flowline is the fundamental flow network consisting predominantly of stream/river and artificial path vector features. It represents the spatial geometry and carries the attributes

Data Resolution: Vector, line

Data Units: Tabular attributes

Creation Method: Data selected from NHD Flowline feature class to contain only FType code 460, StreamRiver (Perennial, Ephemeral, Intermittent) and clipped to the ACCEL boundary.

Data Source: USGS National Hydrography Dataset (NHD); https://www.usgs.gov/national-hydrography/national-hydrography-dataset

File Name: NHD_Streams_Clip

RIPARIAN AREAS

Definition and Relevance: Existing and potential 50-year flood height riparian areas, and a riparian land cover using ESRI global landcover to derive.

Data Resolution: 10m Raster

Data Units: Classified Values

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

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

File Name: riparian_areas.tif; riparian_lulc_esri_2020.tif

FIRE

CURRENT FIRE RETURN INTERVAL DEPARTURE, SINCE 1908

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

Data Resolution: 30m Raster

Data Units: Average Years

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

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

Data Source:

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

File Name: currentFRI.tif

CURRENT FIRE RETURN INTERVAL DEPARTURE, SINCE 1970

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

Data Resolution: 30m Raster

Data Units: Average Years

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

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

Data Source:

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

File Name: currentFRI_1970.tif

POTENTIAL OPERATIONAL DELINEATIONS

Definition and Relevance: Potential Operational Delineations (PODs) are spatial units or containers defined by potential fire control features, such as roads and ridge tops, within which relevant information on forest conditions, ecology, and fire potential can be summarized. The Rocky Mountain Research Station Wildfire Risk Management Science (WRMS) Team co-developed PODs to pre-plan for fire using a risk management approach, and to give land managers a formal process for developing landscape-scale wildfire response options before fires start. PODs combine local fire knowledge with advanced spatial analytics to help managers develop a common understanding of risks, management opportunities, and desired outcomes to determine fire management objectives.

PODs vary in size, are drawn irrespective of jurisdictional boundaries, and correspond to potential control points for a fire such as roads, ridgelines, drainages, previous fuel treatment boundaries, recent burns, or anything else that might give firefighters on the ground an advantage. Where PODs are preplanned, they guide managers in developing initial response strategies and tactics in a particular area in the event of ignition.

The PODs provided here represent conditions as of about 2016. Each forest in CA is the keeper of its own POD data attributes, and the majority of the POD networks on the Sierras are in revision or in need of revision using the current participatory process framework (post-2016). The Inyo, Stanislaus, Tahoe Basin, Lassen, Tahoe, and Eldorado POD networks are being updated. Others will be updated as staff availability permits.

Data Resolution: Vector, polygon

Data Units: Tabular attributes

Creation Method: The process of developing PODs is done collaboratively by local wildland fire managers, stakeholders, and scientists. Collaborators identify a network of best available control features, often using analytical tools to assess the feature's quality and suitability. When paired with a wildfire risk assessment, PODs can be used to quantify and summarize risk into strategic response zones that provide the starting point for strategic planning of incident response.

PODs will need updating through a collaborative process where fire scientists work with local planners and community members to provide a spatial analysis of the entire National Forest or other planning area to delineate/update suitable potential control locations, update the quantitative risk assessment of high resource values, and assess suppression difficulty across the landscape. Updated info0rmatioin will enable delineation or improvement of the POD layout.

Data Source: USDA Forest Service RMRS Wildfire Risk Management Science Team https://www.fs.usda.gov/rmrs/groups/wildfire-risk-management-science-team

File Name: PODs.shp

WILDLAND URBAN INTERFACE

Definition and Relevance: The wildland urban interface (WUI) is the area where urban development is in close proximity to wildland vegetation. WUI data for the conterminous U.S. based on 125 million building locations where buildings intermingle with or abut wildland vegetation according to the Federal Register definitions of the WUI.

Data Resolution: 30m Raster

Data Units: Categorical

Creation Method: The current delineation of the WUI (Carlson et al. 2022) uses a mapping algorithm with definitions of the WUI; two classes of WUI were identified:

1. the intermix, where there is at least 50% vegetation cover surrounding buildings
2. the interface, where buildings are within 2.4 km (1.5 miles) of a patch of vegetation at least 5 km^2 in size that contains at least 75% vegetation.

Both classes required a minimum building density of 6.17 buildings per km^2 (using a range of circular neighborhood sizes).

Data Source: USGS ScienceBase Data Catalog; https://www.sciencebase.gov/catalog/item/617bfb43d34ea58c3c70038f

File Name: MSB_WUI_100m.tif

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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.

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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).

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ADDITIONAL RESOURCES

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

California Department of Fish and Wildlife. California Interagency Wildlife Task Group. 2014. CWHR version 9.0 personal computer program. Sacramento, CA. http://wildlife.ca.gov/Data/CWHR

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

Forest Vegetation Simulator: https://www.fs.usda.gov/fvs/index.shtml and Essential FVS User's Guide: https://www.fs.usda.gov/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf

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

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

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

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

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

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