Northern Sierra Historical Range of Variability and Current Landscape Departure

Executive Summary

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INTRODUCTION

This document is an executive summary of our detailed General Technical Report (GTR) describing our assessment of Historical Range of Variation (HRV) and current departure in vegetation attributes at multiple scales for a portion of the northern Sierra Nevada in California and Nevada. The GTR provides a detailed discussion of the purpose and need for this assessment, a discussion of the historical and contemporary context of the northern Sierra Nevada landscape, justification for the choice of historical reference period, background on the range of variability concept and the use of simulation modeling to quantify it, the scope and major limitations of this assessment, a detailed description of the methods, and a detailed presentation of results and management applications. Here, we provide only a brief summary of the methods and major findings of the assessment.

For this assessment, we focused on a portion of the northern Sierra Nevada corresponding to the extent of the Tahoe Central Sierra Initiative (TCSI) comprised of six focal landscapes that we defined primarily on the basis of Hydrologic Unit Code (HUC) 8th-level watersheds (**Figure 1**).

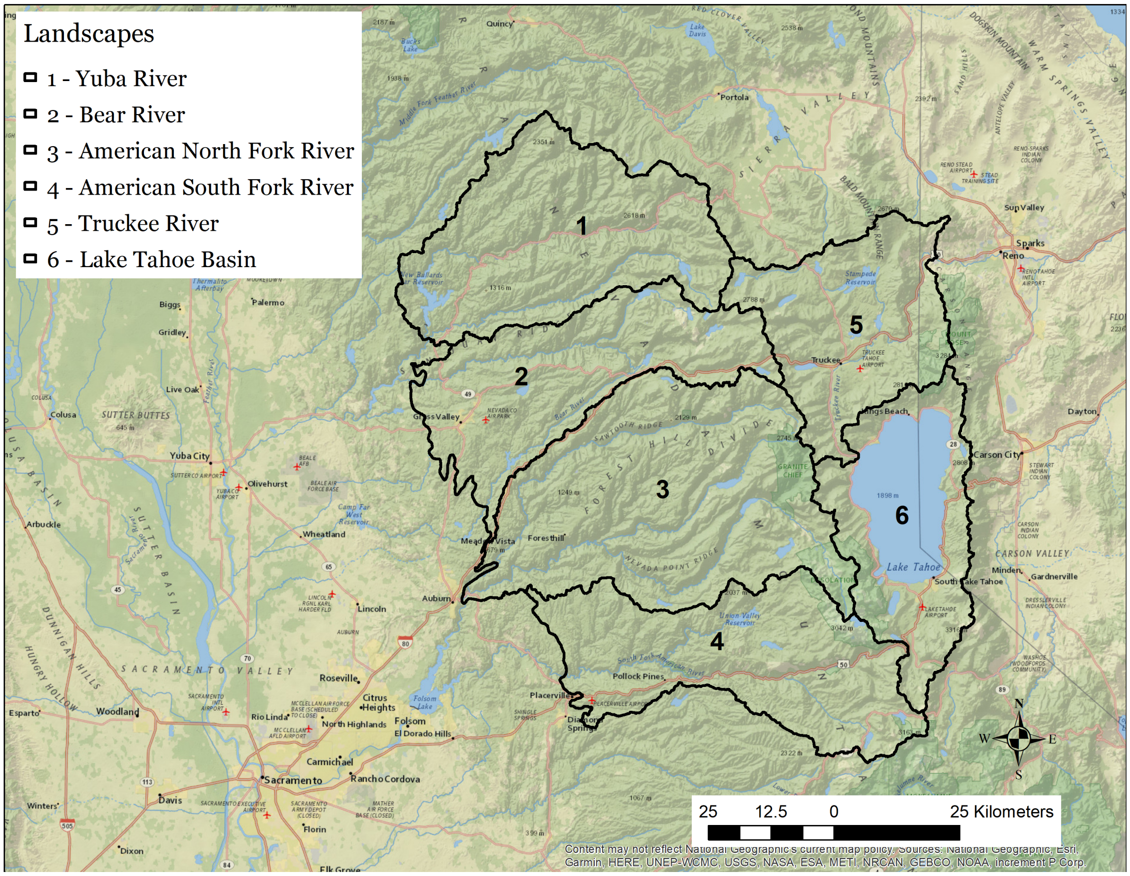

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Figure 1: Project area within the Northern Sierra ecoregion (based on CalVeg Mapping zones), including the extent of the Tahoe Central Sierra Initiative (TCSI) project and comprised of six focal landscapes defined primarily on the basis of Hydrological Unit Code (HUC) 8th-level watersheds for the purpose of simulating wildfire disturbance and vegetation succession.

The northern Sierra Nevada ecoregion is a spatially and temporally dynamic mosaic of ecological systems. This dynamic stems from a complex natural and human land use history, much of which is driven by the interplay of disturbance regimes, especially fire, and vegetation succession, in which cycles of fire and vegetation recovery occur variably over large extents, as well as over long periods of time, and produce a constantly shifting mosaic of ecosystem conditions. Understanding this dynamic is essential to the management of this landscape.

METHODS

We chose to quantify the Natural Range of Variability (NRV) in landscape structure for the selected focal landscapes based on the simulated HRV in several vegetation attributes relevant to forest management. To simulate disturbance and succession processes representative of the historical reference period within the ecoregion, we developed the landscape disturbance-succession simulator LDSim. LDSim is a raster-based, spatially-explicit, stochastic simulator of disturbance and succession processes at the cell level (in this case, 5 m resolution), and is mostly a phenomenological process simulator that seeks to emulate the statistical properties of disturbance and succession processes consistent with the statistical properties of real-world observations.

LDSim simulates succession at the beginning of each timestep in the simulation, representing the establishment, gradual growth and/or development, and eventual senescence of vegetation over time. Disturbance follows succession in each timestep in the simulation and is implemented as a generic disturbance algorithm that can be meaningfully parameterized to represent a variety of natural disturbances, including fire, insects/pathogens and wind, although only fire was simulated in this assessment. Disturbance is implemented as a multi-step process involving climate control, disturbance initiation, spread, termination and mortality, in which each step is optionally constrained by climate (and weather proxies), geophysical setting and vegetation conditions.

LDSim requires a variety of spatial inputs, including cover type, vegetation age and developmental stage, and a variety of geophysical variables. In addition, LDSim has a user-defined set of model parameters that govern the disturbance and succession processes for any particular user-defined application and scenario. Importantly, the parameterization of the disturbance and succession processes represents the set of user assumptions about the system being modeled, and the results are only meaningful in reference to this set of assumptions. In addition, the parameterization of the model is application- and scenario-specific. For this assessment, we parameterized the model to reflect our best, empirically-based understanding of the succession and wildfire disturbance processes characteristic of the historical reference period in the region.

Although LDSim is a process-oriented model with individual parameters sourced either from data, literature, or expert opinion, the model outcomes reflect the complex spatio-temporal interactions of the various stochastic disturbance and succession processes. Consequently, it is necessary to calibrate the model by tuning (i.e., adjusting up or down) one or more of the model parameters to produce selected outcomes that are consistent with the data, literature and expert opinion. Importantly, in this context, we considered the parameters associated with the disturbance process to be “independent” variables and the vegetation conditions (e.g., seral stage distribution, spatial patterns of vegetation states, etc.) to be “dependent” outcomes. We calibrated selected disturbance parameters (i.e., independent variables) to achieve the target disturbance regime without any attention to the vegetation response, which we treated as the dependent outcome of the disturbance regime. Importantly, we did not tune the disturbance regime parameters to achieve desired vegetation outcomes. Specifically, we focused model calibration of five disturbance regime attributes that we considered emergent properties of the disturbance regime: (1) Fire Rotation Period (FRP) by cover type, (2) Fire Mortality Rate (FMR) by cover type, (3) fire size distribution, (4) variability in the total area burned over time, and (5) strength of the relationship between total area burned and climate. For each focal landscape we calibrated the model to achieve target performance criteria for each of these emergent properties.

For each focal landscape, we simulated succession and wildfire disturbance under historical reference period conditions (circa 1550 - 1850) for a 1,500-year period with a 5-year timestep (i.e., 300 timesteps) and output several spatial data layers representing disturbance and vegetation attributes at each timestep. We dropped the first 500 years or 100 timesteps as a liberal estimate of the model equilibration period (i.e., the time to reach dynamic equilibrium) and retained the remaining 1,000 years or 200 timesteps to quantify the range of variability in various landscape attributes (see below). Note, although we simulated landscape dynamics for 1,500 years and retained the last 1,000 years for the analysis of HRV, it is important to recognize that this does not conflict with our ~ 300-year historical reference period. We parameterized LDSim to represent disturbance processes characteristic of the 300-year historical reference period; the longer simulation merely allowed us to produce a larger sample of landscape snapshots that are characteristic of this historical disturbance regime.

It is absolutely essential to interpret the model results in the context of the model parameterization, which is essentially a set of assumptions about how disturbance and succession processes operate at a particular scale in the focal landscape under historical reference period conditions. The choice of scale in representing the landscape is a user assumption that is especially important, as the simulated range of variability and current departure in landscape structure is highly scale-dependent. In other words, the measured variability and current departure depends on the grain and extent of the assessment in both the spatial and temporal domains. Thus, it is imperative that both the spatial and temporal scale, in terms of both grain and extent, of the assessment be made explicit. In this regard, we fixed by design the spatial grain of our assessment at 5 m – the approximate scale of a single mature tree – and the temporal grain at 5 years. In addition, we fixed by design the temporal extent of our assessment at the ~ 300-year historical reference period (circa 1550 - 1850). The spatial extent of our assessment, however, was not fixed by design, and we chose to describe HRV and current departure at a few different scales, or rather "levels" in the hierarchical organization of landscape mosaics: (1) site level, (2) geophysical unit level, and (3) subbasin level, as defined below. Importantly, any attempt to compare our results to those generated at a different scale should be done with extreme caution or, preferably, not at all.

Lastly, to summarize HRV and current departure in landscape structure at the Site and Subbasin levels (see below), we subdivided the landscape into a set of Biophysical Classes (BPCs) based on simulated site productivity. Specifically, we modeled simulated cumulative tree growth (or biomass) as a function of a suite of geophysical predictors and classified predicted cumulative tree biomass under historical dynamic equilibrium conditions into four equal-area BPCs (plus a non-forest class), as depicted in **Figure 2**. We posited that cumulative tree biomass under historical dynamic equilibrium conditions represented an index of realized site productivity that effectively integrated the net effects of all the disturbance and succession processes in LDSim, including, in particular, the frequency and severity of wildfire, the rate of tree establishment and the rate of tree growth after establishment. It is important to acknowledge that BPCs were defined within each focal landscape independently; thus, the BPC classes were relative to the site productivity gradient within each focal landscape. We created BPCs as a means of "packaging" the results in a manner that will be most relevant to management at the project level and would best discriminate differences in the landscape metrics, given the assumption that cumulative tree productivity relates to vegetation characteristics of major interest to land management (e.g., tree cover). We also sought a parsimonious suite of BPCs; i.e., the fewest number of BPCs that would best characterize meaningful differences in the landscape metrics.

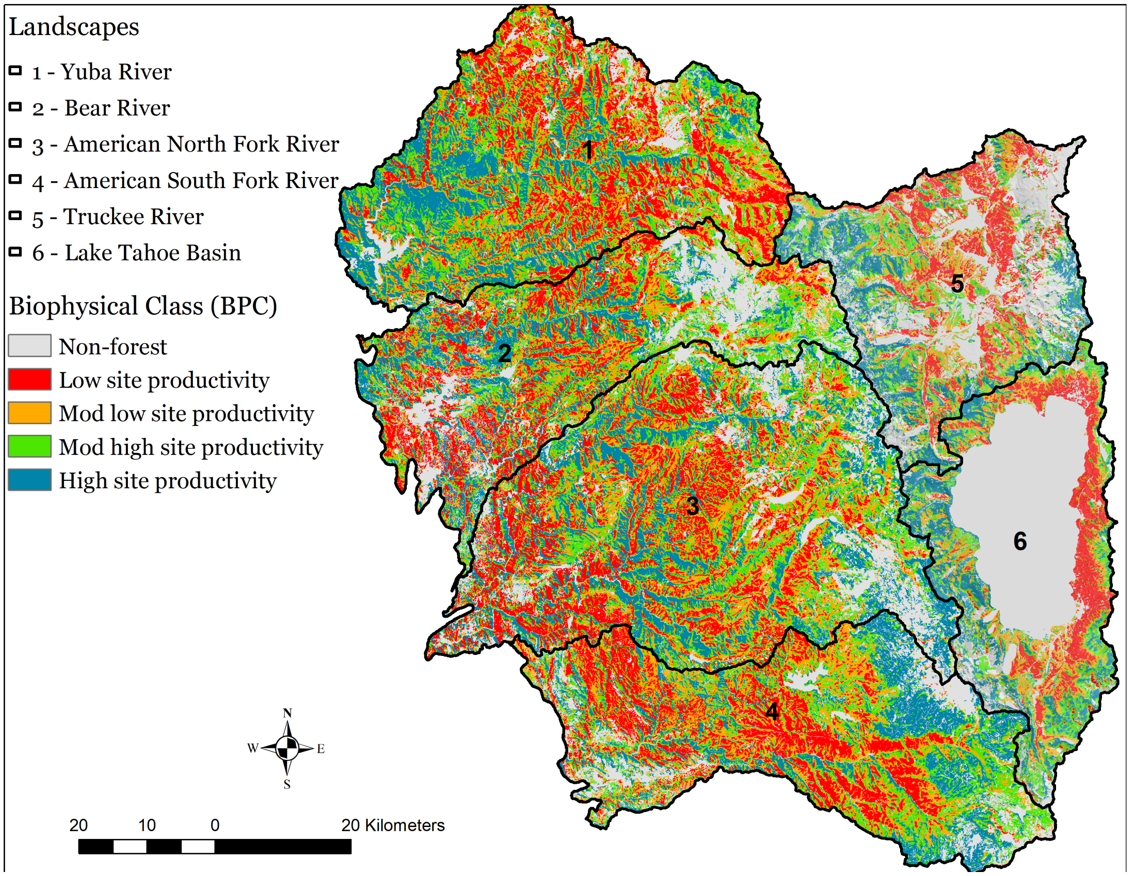

Figure 2: Biophysical Classes (BPCs) based on quartiles of predicted cumulative tree biomass derived from a Random Forest model to predict cumulative tree biomass under historical (i.e., pre-settlement) dynamic equilbrium conditions, as simulated, from 10 biophysical variables, shown here for the Bear River landscape. The Random Forest model explains roughly 70 - 80 % of the variation in Biomass under simulated historical dynamic equilibrium conditions, depending on the landscape.

HISTORICAL RANGE OF VARIABILITY and CURRENT DEPARTURE

Fire Return Interval and Departure

Mean point-specific Fire Return Interval (FRI) represents the average number of years between fire events at the 5 m cell level. We computed mean FRI for the historical reference period by summarizing the interval between fires after model equilibration, as depicted in **Figure 3**. We interpreted the observed mean FRI after model equilibration at the cell level as a single integrated (albeit not comprehensive) summary of the historical wildfire disturbance regime. In addition to the map of cell-level FRI, we also quantified the variation among cells in FRI by BPC (see GTR).

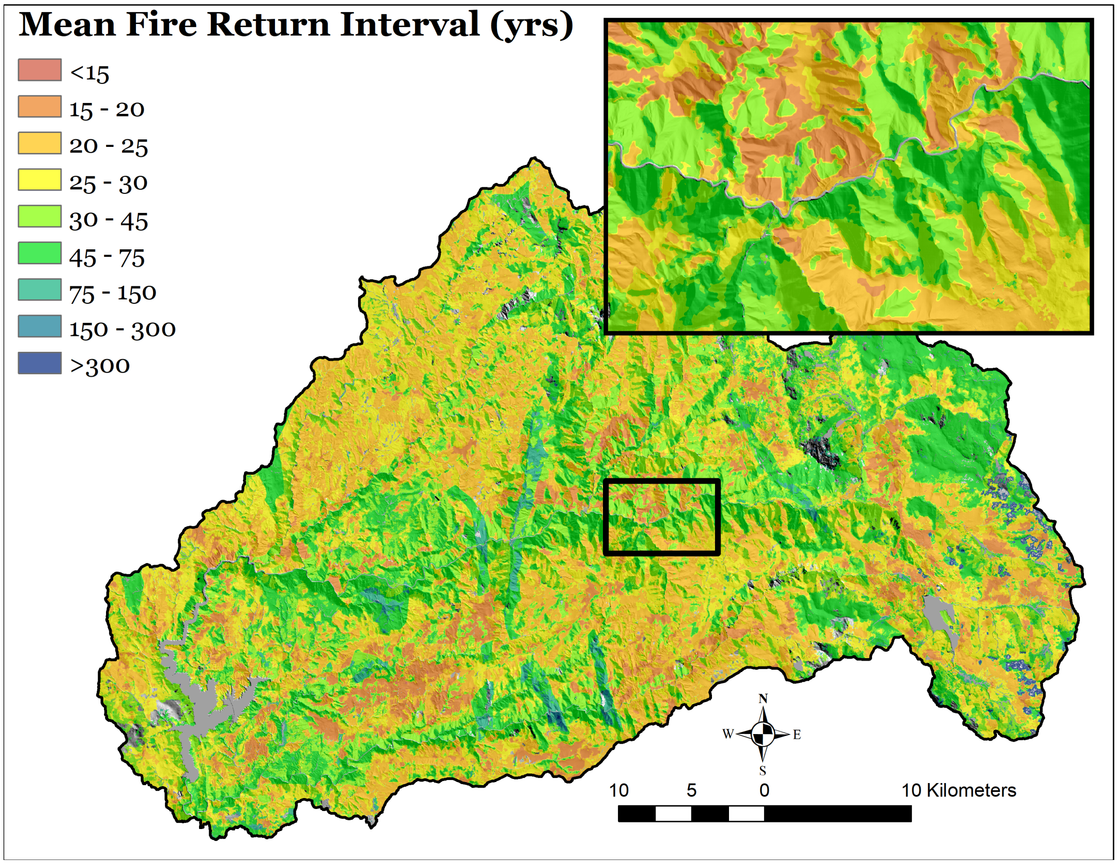

Figure 3: Mean Fire Return Interval (FRI) (yrs) at the 5 m cell level under historical (i.e., pre-settlement) dynamic equilibrium conditions, as simulated.

Fire Return Interval Departure (FRID) represents the percentage deviation of the contemporary (post-settlement) mean point-specific FRI and the mean point-specific FRI under historical (i.e., pre-settlement) dynamic equilibrium conditions, as depicted in **Figure 4**. As computed, if the contemporary FRI is > the pre-settlement FRI, the departure is positive and increases asymptotically to 100 % as the difference between the two FRIs increases; conversely, if the contemporary FRI is < the pre-settlement FRI, the departure is negative and increases asymptotically to -100 % as the difference between the two FRIs increases. Thus, FRID quantifies the extent in percent to which contemporary fires (i.e., since 1909) are burning at frequencies similar to the frequencies that occurred prior to significant Euro-American settlement, as simulated.

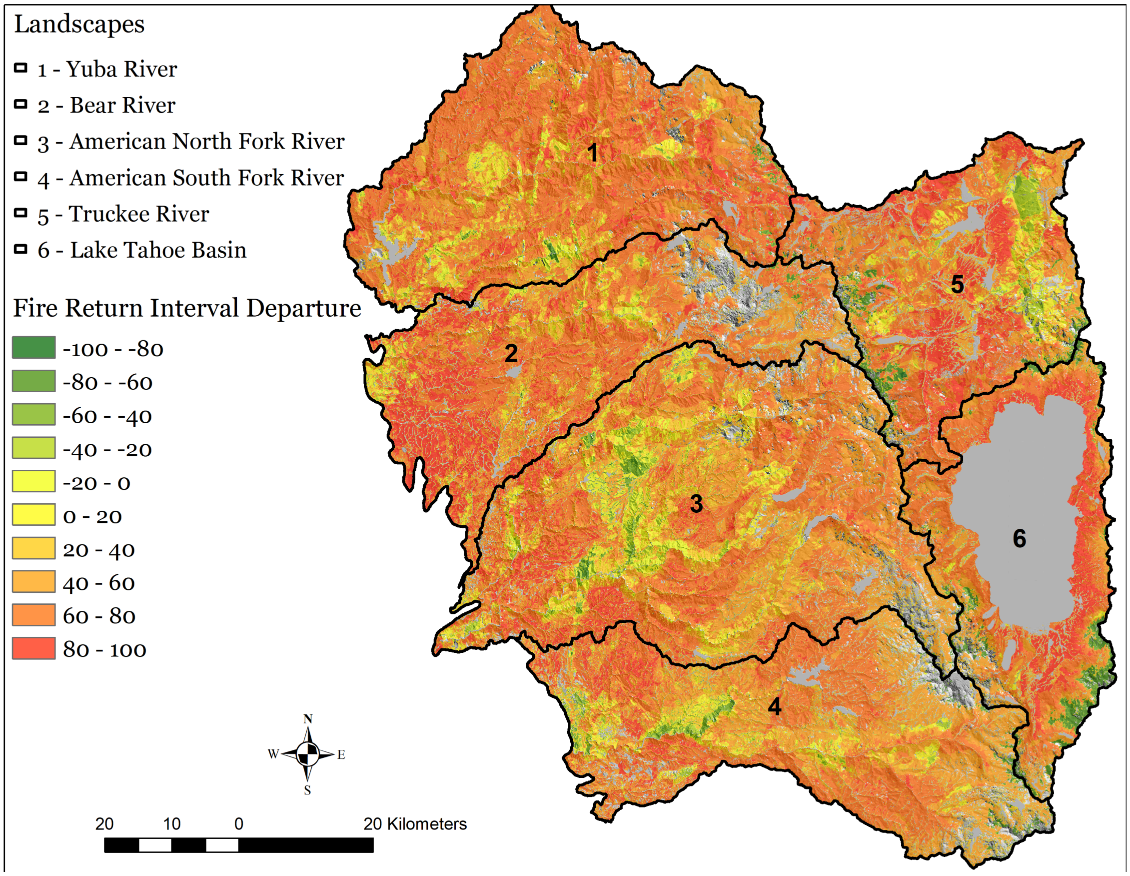

Figure 4: Fire Return Interval (FRI) Departure (FRID) index at the 5 m cell level, representing the percent to which contemporary fires (i.e., since 1909) are burning at frequencies similar to the frequencies that occurred prior to significant Euro-American settlement, as simulated. Positive values represent a contemporary FRI > the pre-settlement FRI and, conversely, negative values represent a contemporary FRI < the pre-settlement FRI.

Briefly, mean FRI and FRID at the cell level can aid unit- and project-level planning and management, as follows:

- FRI at the cell level suggests where and how frequently prescribed fire treatments can be applied to restore the historical fire frequency, subject to other real-world constraints.
- FRID provides a single integrated summary of departure in the fire regime at the cell level that can be used to prioritize where fire is most urgently needed to restore the historical fire frequency – should that be the goal.

Vegetation Persistence

We defined vegetation persistence as the likelihood of persisting in either an early- or late-seral condition at the 5 m cell level, as simulated. We interpreted the observed mean FRI of high-mortality wildfires after model equilibration as a proxy for vegetation persistence, under the assumption that locations with shorter high-mortality FRIs would likely persist longer in early-seral stages and, conversely, locations with longer high-mortality FRIs would likely persist longer in late-seral stages - at least under historical dynamic equilibrium conditions, as depicted in **Figure 5**.

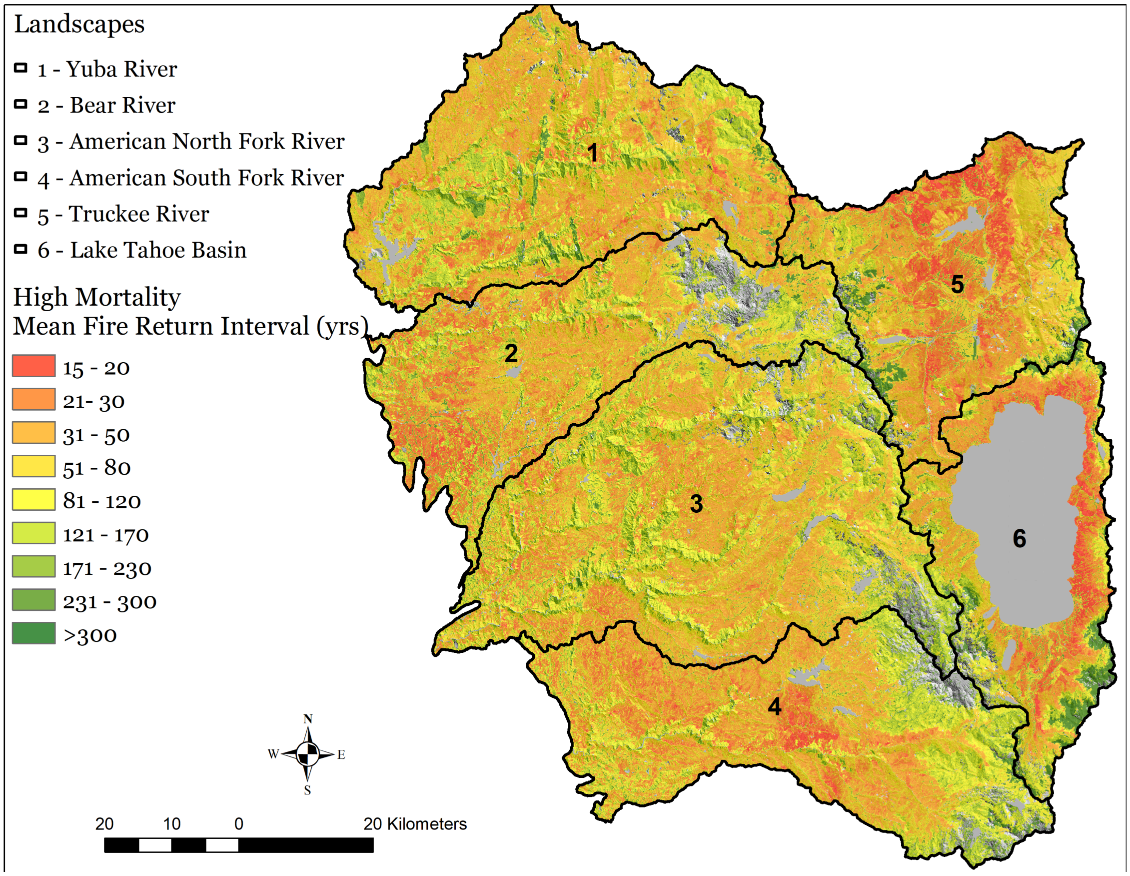

Figure 5: Mean High-mortality Fire Return Interval (FRI) (yrs) at the 5 m cell level under historical (i.e., pre-settlement) dynamic equilibrium conditions, as simulated.

Briefly, high-mortality FRI at the cell level provides a proxy for vegetation persistence that can aid in the spatial planning and management of vegetation treatments, as follows:

- Areas with a longer high-mortality FRI have a greater likelihood of persisting in late-seral forest conditions under the forcings of natural wildfire disturbance, all other things being equal, and can be used to identify priorities for managing habitat for late-seral dependent species such as the California spotted owl (*Strix occidentalis occidentalis*).
- Areas with a shorter high-mortality FRI have a greater likelihood of persisting in early-seral forest conditions under the forcings of natural wildfire disturbance, all other things being equal, and can be used to identify priorities for creating and maintaining large forest openings that provide habitat for early-seral dependent species.

Site Level HRV and Departure

We quantified HRV and computed several departure metrics at the “Site” level, which we defined as a 40-m radius window around each focal cell corresponding to the height and ecological neighborhood of a single “tall” tree in our classification of developmental stages. Thus, Sites represent moving windows (i.e., overlapping windows) across focal cells. We further classified each Site into one of several BPCs to better distinguish among Sites varying in overall forest productivity. Importantly, we considered Site to be the finest scale for which we could reliably compute many vegetation characteristics. However, we deemed it unreliable to compare the current condition of a Site to its own HRV because of the small size of a Site, given the stochastic nature of disturbance and succession processes. Thus, we did not derive an HRV or compute departure for each individual Site. Rather, we defined HRV at the Site level as the variation in the landscape metrics across Sites and over time under historical dynamic equilibrium conditions, thus representing spatio-temporal variability in vegetation conditions across Sites over the full extent of the focal landscape, rather than for each Site individually. Site-level departure is based on a comparison of the current range of variation (CRV) across Sites to the HRV across Sites and time; i.e., departure represents the degree of non-overlap between these two distributions.

We quantified Site-level departure for three vegetation attributes:

- *Developmental stage* - discrete stages of canopy height development: Open, Sapling, Pole, Small Tree, Medium Tree, and Tall Tree. We quantified the composition of forest developmental stages based on the percentage of the forested portion of the Site in each developmental stage.
- *Tree Size* - Quadratic Mean Diameter (QMD) of established trees within a 40-m radius of the focal cell.
- *Tree Cover* - percentage of 5-m cells with established trees to breast height. Note, as computed here, Tree Cover represent the percentage of cells within 40 m containing one or more established trees to breast height, not actual tree canopy cover, and as such is a biased (high) index of actual tree canopy cover (i.e., actual tree canopy cover will be less than reported here, estimated to be on average ~ 16 %).

As an example, the comparative CRV and HRV distributions for developmental stages on High productivity Sites in one of the focal landscapes is depicted in **Figure 6**. In this example, departure in the Open and Tall Tree stages is most notable, with an overall departure index, as measured by the Percentage Dissimilarity between distributions, of ~ 23 %.

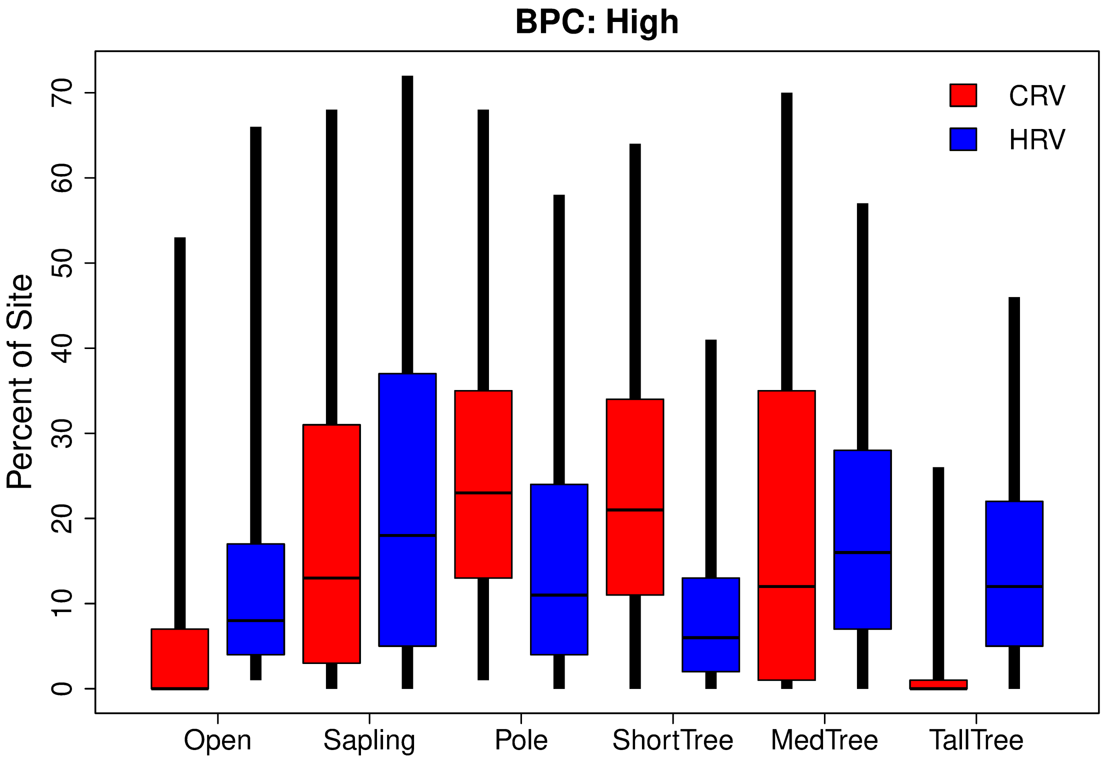

Figure 6: Current Range of Variation (CRV) and Historical Range of Variation (HRV) in the percentage of a Site (40-m radius window centered on a 5 m focal cell) in each forest developmental stage on High productivity Sites in one of the focal landscapes. The median value is represented as a solid black horizontal line, the 25 - 75th quantiles as the box, and the 2.5 - 97.5th quantiles as solid black lines (a.k.a. whiskers) extending outward from the box.

Briefly, Site-level results can aid unit and project-level planning and management, as well as watershed-level monitoring of vegetation conditions over time, as follows:

- HRV results can provide loose quantitative targets for the distribution of vegetation conditions to be achieved across all Sites over the full extent of the landscape (albeit within BPCs).
- Comparing the CRV distribution to the HRV distribution can provide a quantitative basis for estimating current departure, and in this regard our departure index provides a single quantitative summary of the deviation between these two distributions that can serve as a benchmark for measuring where we are today. Recomputing the departure index after some period of vegetation treatments (real or simulated) can be used to determine the magnitude and rate of change resulting from the treatments, and thus serve as the quantitative basis for monitoring landscape changes under the auspices of adaptive management.

Geophysical Unit Level Departure

We quantified HRV and computed several departure metrics at the “Geophysical Unit” (GPU) level. We derived GPUs through a series of geoprocessing steps to create meaningful spatial units (minimum of 10 acres and mean of ~50 acres) that differ in one or more geophysical attributes from adjacent units so as to be distinguishable in terms of geophysical characteristics and presumably different enough to potentially affect disturbance and succession processes (and thus resulting vegetation patterns), and also be meaningful for management purposes (i.e., roughly corresponding to the scale of potential treatment units). Vegetation conditions were not considered in delineating GPUs so as to not bias the HRV and current departure results. Importantly, we deemed it reliable to compare the current condition of a GPU to its own HRV because it is sufficiently large enough to do so. Thus, we derived an HRV and computed departure for each GPU independently (in contrast to the Site-level HRV and departure).

We quantified GPU-level departure for the following metrics, which we deemed meaningful for estimating departure at the GPU level and appropriate given the available data, and solely for the purpose of prioritizing units for treatments aimed at restoring HRV conditions. For each metric, we compared the current condition of the GPU, given by a single value, to the HRV of the GPU based on the variability in the landscape metric under historical dynamic equilibrium conditions, and derived a departure index to reflect how far the current condition is from the HRV.

- *Basal Area* - Cross-sectional area of trees at breast height per unit area, based on the basal area departure score developed by the TCSI project. We chose this metric because of the importance of basal area as an integrator of stem density and stem diameter and the important role this metric plays in the design of silvicultural treatments.
- *Percent Open Forest* - percentage of cells in the Open developmental stage. We chose this metric because of the importance of Open canopy conditions in the restoration of forest vegetation and the dominant role this metric plays in the design of silvicultural treatments.
- *Developmental Stage Diversity* - diversity of developmental stages based on the Simpson’s Diversity index. We chose this metric to capture GPUs in which there is too little diversity in developmental stage composition relative to HRV.
- *Coefficient of Variation in Open Patch Size* - Coefficient of Variation (CV) in the size of all Open patches, including single cell patches, in which forest openings are defined by contiguous cells in the

Open developmental stage based on the 4-neighbor rule (i.e., adjacent cells of the same class must share a full side to be considered in the same patch). Note, Open patches here are not the same as "large" openings, which we define later for use at the Subbasin-level. We chose this metric to capture GPUs in which there is too little heterogeneity in the size of Open patches relative to HRV.

- *Coefficient of Variation in Developmental Stage Patch Size* - CV in the size of all developmental stage patches, including single cell patches, in which patches are defined by contiguous cells in the same developmental stage based on the 4-neighbor rule. We chose this metric to capture GPUs in which there is too little heterogeneity in the size of developmental stage (or canopy height) patches relative to HRV.

- *Percent Large Trees* - percentage of cells in the Large tree size class ($\geq$ 30 in dbh) within the GPU, which is a measure of landscape *composition*. We chose this departure metric because of the importance of Large trees to wildlife and the important role this metric plays in the design of silvicultural treatments.

- *Tree Size Class Diversity* - diversity of tree size classes based on the Simpson's Diversity index. We chose this metric to capture GPUs in which there is too little diversity in tree size class composition relative to HRV.

- *Coefficient of Variation in Large Tree Patch Size* - CV in the size of all Large tree patches, including single cell patches, in which Large tree patches are defined by contiguous cells in the Large tree class ($\geq$ 30 in dbh) based on the 4-neighbor rule. We chose this metric to capture GPUs in which there is too little variability in the size of Large tree patches relative to HRV.

- *Coefficient of Variation in Tree Size Class Patch Size* - CV in the size of all tree size class patches, including single cell patches, in which patches are defined by contiguous cells in the same tree size class based on the 4-neighbor rule. We chose this metric to capture GPUs in which there is too little heterogeneity in the size of tree size class patches relative to HRV.

- *Coefficient of Variation in Quadratic Mean Diameter* - CV in Site-level Quadratic Mean Diameter (QMD) of established trees. Recall that QMD is computed for the Site associated with each focal cell, which produces a continuous surface of QMD values, from which the CV in QMD is computed. We chose this metric to capture GPUs in which there is too little spatial heterogeneity in the weighted average tree size (i.e., QMD) relative to HRV.

- *Coefficient of Variation in Percent Tree Cover* - CV in Site-level percent cover of established trees. Recall that percent tree Cover is computed for the Site associated with each focal cell, which produces a continuous surface of percent tree cover value, from which the CV in tree cover is computed. We chose this metric to capture GPUs in which there is too little spatial heterogeneity in percent tree cover relative to HRV.

We combined the 11 GPU-level departure metrics above dealing with vegetation composition and configuration into two different composite departure metrics: negative and absolute departure, both of which are given as a percentage of theoretical maximum departure:

- *Negative Departure* - maximum "negative" departure occurs when GPUs have too little Open forest area, too few Large trees, too little diversity in forest developmental stages (i.e., tree heights) and tree size classes (i.e., dbh), too little variability in the size of patches based on forest developmental stage and tree size, and too little spatial variability in percent tree cover and weighted average tree size (i.e., QMD) relative to HRV. In other words, maximum departure occurs when the forest is too closed-canopy, depauperate in Large trees, and too homogeneous in vegetation composition and configuration. Note, this composite departure score focuses on GPUs that depart from HRV in one or more aspects of forest vegetation composition and configuration in the direction that is of most concern regarding ecological restoration of historical reference conditions.

- *Absolute Departure* - maximum "absolute" departure occurs when GPUs have either too little or too much Open forest area, too few or too many Large trees, too little or too much diversity in forest developmental stages (i.e., tree heights) and tree size classes (i.e., dbh), too little or too much variability in the size of patches based on forest developmental stage and tree size, and too little or too much spatial variability in percent tree cover and weighted average tree size (i.e., QMD) relative to HRV. In other words, maximum departure occurs when the GPUs differ in both composition and configuration from their HRV in any direction, as measured by this suite of metrics.

As an example, the GPU-level composite negative departure score for one of the focal landscapes is depicted in **Figure 7**. The map illustrates strong local variation in GPU-level departure, with individual GPUs ranging in departure from near zero to > 50 % of the theoretical maximum possible departure.

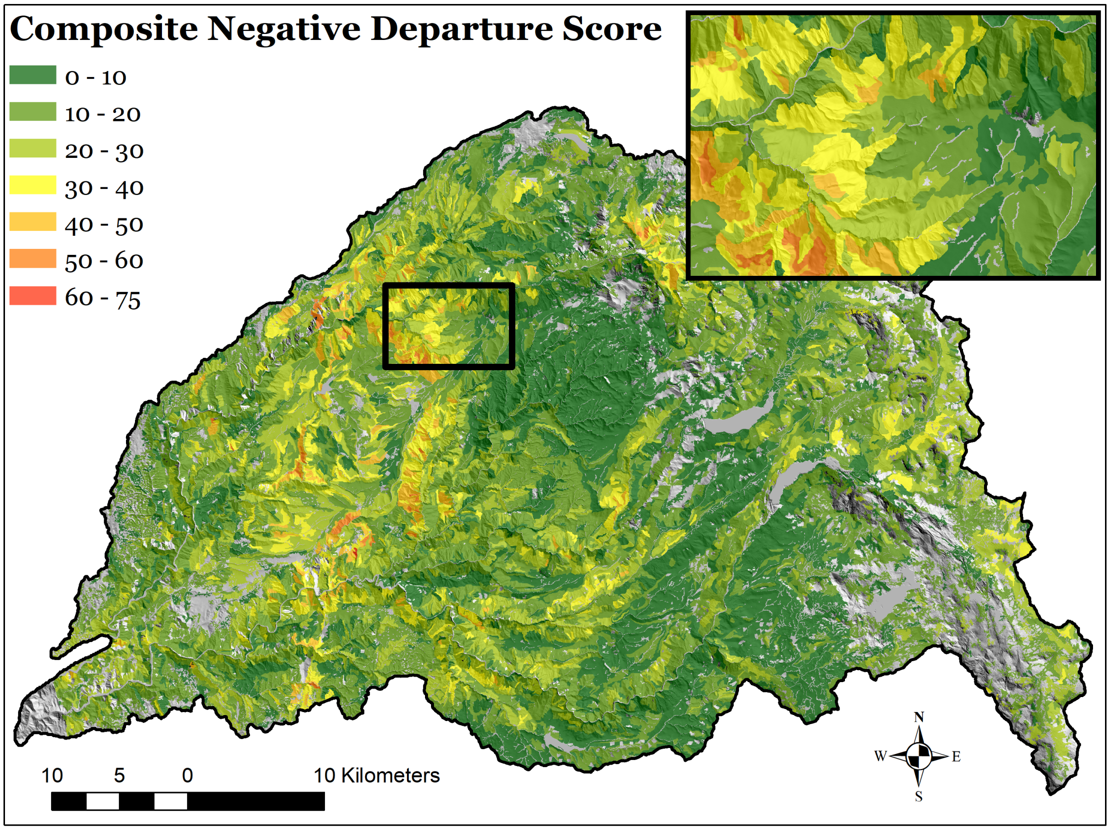

Figure 7: Composite Negative Departure Score for the Geophysical Units (GPUs) in the American North Fork River landscape. The composite departure score represents the weighted average of 11 component departure metrics and is given as the percent of theoretical maximum departure (see text for details).

Briefly, GPU-level results can aid unit and project-level planning and management. However, in contrast to Site-level results, which are best used to describe HRV and departure across the entire focal landscape as a whole, GPU-level results excel in quantifying HRV and departure at the local unit level, as follows:

- Identify and prioritize local areas that depart from HRV, along with the nature and magnitude of that departure. Recall, the "negative" departure index identifies units in which the current condition of the unit has a value for the corresponding metric that is less than the HRV for the unit. The "absolute" departure index, on the other hand, identifies units in which the current condition of the unit simply differs from the HRV in either direction.

- The geophysical descriptors for each GPU can be used to query the data to create GPU subsets of interest.
- Provide loose qualitative and/or quantitative targets for desired vegetation conditions within each unit – should restoration of historical reference conditions be the objective. Importantly, the HRV for each GPU provides a range of reference conditions, not a single condition, providing a great deal of flexibility in designing treatments that meet multiple objectives.
- Provide a quantitative means of monitoring treatment effectiveness. Specifically, GPU departure indices provide detailed, specific and quantitative measures of current departure from HRV, and thus provide a benchmark for measuring where we are today, and can be used to determine the magnitude and rate of change resulting from vegetation treatments pursuant to adaptive management.
- GPU-level departure is being incorporated into a first-of-its-kind land management and planning tool called Land Tender (https://www.vibrantplanet.net/landtender) to help develop and prioritize forest health treatment projects.

Subbasin Level Departure

We quantified HRV and computed several departure metrics at the "Subbasin" level, which we defined by Hydrologic Unit (HUC) 12th-level watersheds. We further partitioned each Subbasin into BPCs to better distinguish among sites varying in overall forest productivity. Importantly, we consider a Subbasin to be a meaningful "landscape" for characterizing vegetation dynamics; it is large enough to capture coarse-scale patterns resulting from disturbance and succession processes, yet small enough to capture the idiosyncrasies of non-stationary landscape processes. In lieu of having a comprehensive suite of designated project areas for the region, we deemed HUC12 Subbasins as a practical surrogate and an appropriate scale for project-level planning and management, since HUC12 Subbasins generally encompass 10,000 - 25,000 acres - roughly the scale of most National Forest NEPA projects. Like the GPU-level assessment, here we compared the current condition of a Subbasin-by-BPC partition to its own HRV and computed departure for each partition independently.

We quantified Subbasin-level departure for the following metrics, which we deemed meaningful for estimating departure at the Subbasin level and appropriate given the available data. For each metric, we compared the current condition of the Subbasin-by-BPC partition, given either by a single value or a distribution of values depending on the metric, to the HRV of the partition based on the variability in the landscape metric under historical dynamic equilibrium conditions, and derived a departure index to reflect how far the current condition is from the HRV.

- *Percent Large Forest Openings* - percentage of the landscape partition in large forest openings, defined as contiguous forested cells based on the 4-neighbor rule in the Open developmental stage (i.e., no established trees to breast height) encompassing a minimum of 0.04 ha (0.1 acres). Our definition is not to be confused with how large forest openings have been defined in other applications, and thus any comparison with other studies must be done with care. The departure index reflects whether or not the current landscape is deficient in large forest openings relative to HRV and, if so, the degree of deficiency. We chose this metric to identify Subbasins and BPCs in which there is too little area in large forest openings relative to HRV.
- *Large Forest Openings Patch Size Distribution* - percentage of the landscape partition in large forest openings (as defined above) in each of several patch size classes or bins. The departure index represents the Percentage Dissimilarity between the current and historical patch size distributions. We chose this metric to identify Subbasins and BPCs in which the current landscape has too few or too many large forest openings in each of several patch size classes relative to HRV.
- *Developmental Stage Patch Size Distribution* - similar to the previous metric except that patches of all developmental stages ranging from Open ($<$ 4.5 ft) to Tall Trees ($>$ 125 ft) were considered. We

chose this metric to identify Subbasins and BPCs in which the current landscape has a forest that is too homogeneous in canopy height or too uniform in the canopy height patch mosaic relative to HRV.

- *Percent Large Trees* - percentage of the landscape partition in large trees (> 30 inch dbh). The departure index reflects whether or not the current landscape is deficient in large trees relative to HRV and, if so, the degree of deficiency. We chose this metric to identify Subbasins and BPCs in which there is too little area in large trees relative to HRV.
- *Large Tree Patch Size Distribution* - percentage of the landscape partition in large trees (as defined above) in each of several patch size classes or bins. The departure index represents the Percentage Dissimilarity between the current and historical patch size distributions. We chose this metric to identify Subbasins and BPCs in which the current landscape has too few or too many large tree patches in each of several patch size classes relative to HRV.
- *Tree Size Class Patch Size Distribution* - similar to the previous metric except that patches of all tree size classes ranging from Open (< 1 in dbh) to large Trees (> 30 in dbh) were considered. We chose this metric to identify Subbasins and BPCs in which the current landscape has a forest that is too homogeneous in tree size or too uniform in the tree size patch mosaic relative to HRV.

We combined the 6 Subbasin-level departure metrics above dealing with vegetation composition and configuration into a single composite departure score, which is given as a percentage of theoretical maximum departure, as depicted in **Figure 8** . Maximum departure occurs when the forest has too little area in large forest openings and/or large trees, and/or a vegetation patch mosaic configuration defined on the basis of either developmental stages (or tree height classes) or tree size classes (or tree diameter classes) that differs from the corresponding patch mosaic configuration under historical dynamic equilibrium conditions (i.e., too little or too much spatial variability). The map illustrates strong variation in Subbasin-level departure, with individual landscape partitions ranging in departure from 30 - 90 % of the theoretical maximum possible departure.

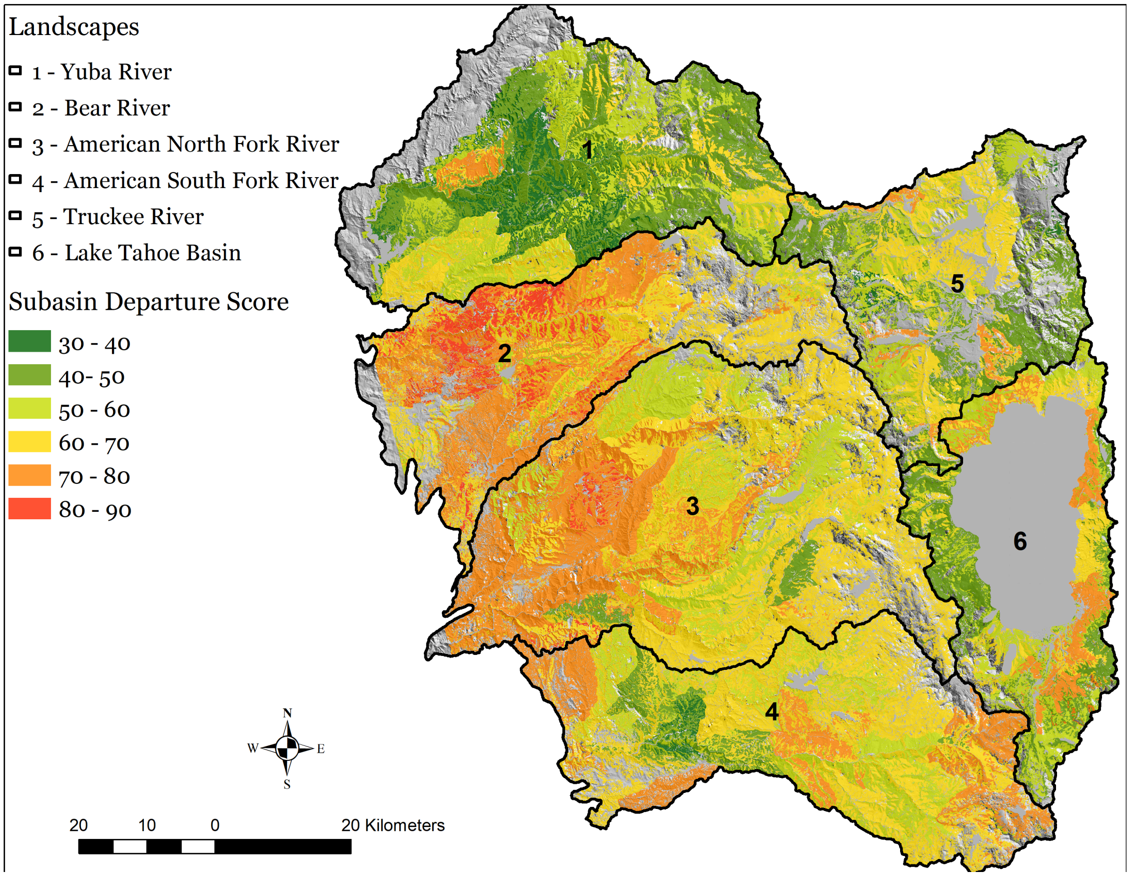

Figure 8: Composite Departure Score Subbasin-by-Biophysical Class (BPCs) partitions. The composite departure score represents the simple average of 6 component departure metrics and is given as the percent of theoretical maximum departure (see text for details).

Briefly, Subbasin-level results can aid project-level planning and management, as follows. Recall that Site-level results provide a perspective on HRV and departure at the scale of the entire focal landscape, albeit by evaluating conditions across plot-like Sites, and GPU-level results provide a local perspective on HRV and departure for areas large enough to consider the results as reliable and yet small enough to reflect spatial units akin to potential treatment units. Subbasin results, on the other hand, provide a perspective on HRV and departure at an intermediate scale - that of small landscapes embedded within the larger focal landscape.

- Serve as a first stage in identifying and prioritizing Subbasins and BPCs for treatment - should restoration of historical reference conditions be the goal. Specifically, Subbasin departure can point to broad areas within the focal landscape that exhibit the greatest departure from HRV, and the departure of individual BPC partitions within the Subbasin can point to the parts of the Subbasin that depart the most.
- Specific objectives and treatments for each potential project area can be informed by decomposing the composite score into the component metrics to determine which aspects of the forest vegetation composition and/or configuration are departed and to what degree.