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California Wildfire Resilience Core Metrics Rating Process and Results

September 2023 – March 2024

Prepared for the California Wildfire & Forest Resilience Task Force

by

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Photos: Top row, left to right: Fire in the Wildland-Urban Interface (CALFIRE), Giant Sequoia Emergency Response USFS crew (USFS Region 5), Little Lakes Valley, Eastern Sierra (Jeff Pang); Bottom row, left to right: interagency archeology and cultural fire workshop with tribal members near Mariposa, CA (CALFIRE), Sequoia Kings grove (National Park Service, nps.gov).

Executive Summary

The California Wildfire & Forest Resilience Task Force (Task Force) has developed regionally-adapted resources to lessen wildfire risk to communities and enhance broader statewide ecosystem resilience. This includes a large set of metrics intended to support a wide range of organizations in prioritizing, planning and/or implementing management actions. The Science Advisory Panel to the Task Force (SAP) was asked to provide expert advice to inform the selection of a subset of "core" metrics for reporting outcomes and progress towards resilience goals. We used survey tools to collect and synthesize the scientific expertise of the SAP as well as other experts regarding existing "Regional Resource Kit" (RRK) metrics as well as potential suggested metrics. This report summarizes the survey process and results.

We used two rounds of surveys to collect expert opinion on metrics. Round 1 asked respondents to 1) identify criteria for core metrics, 2) identify metrics from the Regional Resource Kits (RRKs) that were believed to be inadequate based on those criteria, and 3) recommend additional metrics not included in the original set. Round 2 asked respondents to rate the resulting set of 115 metrics. The Round 1 results indicated that selecting a useful set of core metrics depended on their intended application (e.g., planning vs.reporting), the intended audience (e.g., policy makers, scientists, and/or the public), and resilience outcomes (e.g., immediate wildfire risk reduction versus long-term ecological health). In Round 2 we asked respondents to rate each metric on how well it measured each of three broad, overlapping resilience goals identified by the Task Force: 1) reducing wildfire risk, 2) improving ecological integrity, and/or 3) supporting social and/or cultural wellbeing. The Task Force specified the purpose for the metrics: reporting progress to policymakers and the public. Therefore, respondents also evaluated three attributes for each metric: 1) how realistic it was to remeasure (i.e., feasibility), 2) how easy it was to explain to wide audiences (i.e., understandability), and 3) how well it represented the process of interest (i.e., sensitivity). In addition, respondents identified relevant region(s) of California (Sierra Nevada, Southern California, Central Coast, and Northern California) for each metric.

For the 115 metrics collectively considered in Round 2 (81 from the RRKs and 34 novel metrics), 66 received an average rating of greater than 4 out of 5 on one or more of the three resilience goals (reduce fire risk, improve ecological resilience, support social/cultural wellbeing). Of these, 13 metrics were rated above 4 out of 5 for two of the three goals, and only "probability of high-severity fire" was rated that highly for all three. Metrics on topics relating to vegetation structure and composition as well as fire behavior and history were most abundant in the RRKs and in our list of highly rated metrics. Topics relating to air quality, water supply, economics, community readiness, environmental justice, and community wellbeing were less abundant in the RRKs and not as highly rated in our surveys; these topic areas could benefit from further expert feedback and development.

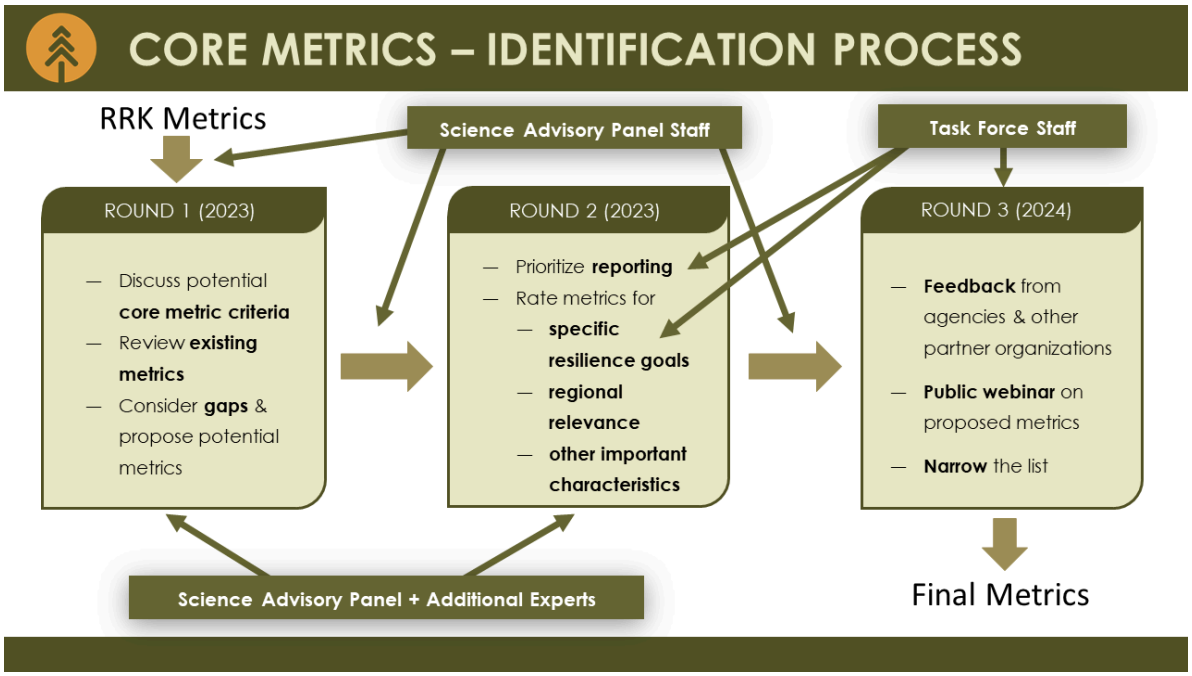
Top-rated metrics already present in the RRKs included: probability of high severity fire, damage potential in the Wildland-Urban Interface (WUI), standing dead and ladder fuels, vegetative stress during extreme drought, tree mortality, and shrub resilience. Metrics that are not yet in the RRKs but do exist elsewhere include Cal EnviroScreen scores and areas of low potential shrub regeneration. Highly rated novel metrics suggested by the survey respondents include (among others): health outcomes related to air quality/smoke and insurance availability/price. Some considerations for proceeding with selection of core metrics arose through this process. First, metrics selected (and targeted desirable ranges for these metrics) might be ecosystem specific. Second, the tradeoff between the logistical aspects of the metrics (feasibility of remeasurement, understandability) with their scientific accuracy and value needs to be evaluated with the target audience in mind. Third, many metrics can address resilience across multiple topic areas and therefore framing this overlap carefully is important when determining how to track progress towards resilience goals.

Table of Contents

Survey Approach and Methods

At the request of Task Force leadership, the Science Advisory Panel (SAP) developed an approach to provide timely science support for their effort to identify core metrics for reporting purposes. We used a structured process of science review characterized by sequential rounds of surveys with questions defined by policy-led information needs (Figure 1). See Appendix A for specific language from the surveys.

Figure 1: Diagram outlining the Task Force effort to define core metrics.



Overview:

- Prior to this project, an interagency team of scientists curated and compiled a large number of metrics as part of each Task Force Regional Resource Kit (RRK). SAP Staff started with a slightly simplified list of metrics compiled from all four RRKs.
- The Round 1 survey asked experts to offer feedback on the proposed core metric criteria, to indicate whether any current RRK metrics were definitely not suitable (1-5 rating, from unsuitable to suitable), and to suggest additional high-priority metrics that were missing from the RRKs (as well as potential resources for generating or obtaining those proposed metrics).
- Based on responses from Round 1, SAP staff removed metrics with an average rating less than 3 out of 5 and added suggested metrics to the candidate list.
- The Task Force staff clarified the priority purpose for identifying core metrics, namely for high-level (e.g., Legislature, Governor's Office) reporting of fuel treatment efficacy. Task Force staff also specified the three resilience goals: wildfire risk reduction, ecological integrity improvement, and social/cultural wellbeing support. The assignment to the SAP was to evaluate core metrics for their suitability to measure progress toward these goals.
- The Round 2 survey asked experts to: 1) rate the usefulness of each metric for measuring progress towards the three resilience goals, 2) rate each metric on their

attributes related to feasibility of remeasurement, understandability to wide audiences, and sensitivity to the process of interest, and 3) indicate for which regions of California each metric was relevant (see Figure 2 for regions and Table 1 for definitions).

- Both Round 1 and Round 2 surveys also offered the opportunity for free-form comments on each metric in the list.
- SAP staff prepared this summary of the survey results and sent a complete draft to the survey respondents. Twelve of the 38 respondents replied and several gave detailed comments on the draft, which SAP staff incorporated into the final version.

Table 1: Definitions for the three resilience goals and metric attributes rated in Round 2 surveys.

Goal	**Description**
Reducing Wildfire Risk	Focused on community protection and safety, especially in and around the Wildland-Urban Interface (WUI).
Improving Ecological Integrity	Reducing large high-severity wildfires that compromise, for example (but not limited to) biodiversity, watershed services, carbon stocks, etc.
Supporting Sociocultural Wellbeing	Focused on forest product/recreation economies, household financial stability, benefits or harm associated with wildfire and vegetation management actions, environmental justice concerns, and other social and cultural benefits.
Attribute	**Description**
Feasibility	Feasibility of data access, analysis, and/or ability to remeasure the metric as-needed (ideally annually but at least every 5 years).
Understandability	How challenging a metric is to understand and explain to managers, policymakers, or members of the public.
Sensitivity	How well the metric detects change in the process of interest.

Figure 2: Regions of California covered by the Regional Resource Kits

Round 1 Survey Details

From the metrics included in Version 1 of the Regional Resource Kits (RRKs), those related to individual sensitive species were collapsed into a single composite metric (i.e any “individual species-related metric”). All other metrics were included as described in the RRK.

The round 1 survey asked respondents to (1) review and edit proposed criteria for including a metric in the core subset, (2) identify any metrics that should be considered for the core subset and were not included in the regional resource kits, and (3) eliminate metrics which were in the kits, but did not meet the proposed criteria for core metrics. Respondents reviewed only those metrics that were related to their self-identified disciplinary areas (Table 2) in order to make more efficient use of their time. Respondents could select more than one discipline, and metrics which related to two or more disciplinary areas were displayed if any one of the associated disciplines were selected.

Table 2: Description of Disciplinary Areas for selection in both surveys.

Disciplinary area	**Topics included**
Vegetation Ecology	Including forest ecosystems, chaparral ecosystems, grassland ecosystems, urban ecosystems, plant physiology, and/or other vegetation-related topics
Fire Ecology	Including fuels and fire behavior modeling, fire dynamics and/or fire ecology
Biodiversity	Including conservation biology, wildlife ecology, threatened and endangered species, and/or other wildlife related topics
Hydrology and Watershed Sciences	Including watershed processes, hydrological systems modeling, and/or other water related topics
Ecosystem Management	Including forest, shrublands, and/or grasslands management, ecosystem services, community ecology, reforestation or restoration, and/or the built environment
Climate Science	Including climate adaptation science, nature-based solutions, atmospheric, climate, and emissions modeling, carbon accounting and modeling
Social Sciences	Including economics, sociology, community development/engagement, Native American studies and/or other disciplines and topics relevant to socio-ecological resilience, for example socioeconomic expertise related to disadvantaged communities, recreation uses, and rural livelihoods

Round 2 Survey Details

The Round 2 survey asked experts to: 1) rate the usefulness of each metric for measuring progress towards each of the three resilience goals (reducing wildfire risk, improving ecological integrity, and supporting social and cultural wellbeing), 2) rate each metric on their attributes related to feasibility, understandability, and sensitivity to the process of interest, and 3) indicate

for which regions of California each metric was relevant (Sierra Nevada, Southern California, Central Coast, and Northern California) (see Figure 2 for regions and Table 1 for definitions).

Additionally, before viewing and rating the list of candidate metrics, respondents were asked to rate the importance of the three resilience goals, relative to each other and, similarly, the importance of the three attributes of core metrics. These ratings were meant to help give context to the relative importance of ratings on different goals or attributes and were used to create 'composite' scores for each metric combining the three goals into one weighted score, and likewise for the three attributes.

Round 2 of the surveys grouped metrics by topic; these topical groupings were created by the SAP staff. The groupings were intended to organize the survey for efficient response, and were not vetted extensively by additional experts; they do not perfectly align with the Pillars of Resilience or their sub-groupings of "Elements," though they are related.[1] For example, the water-related metrics in the RRKs are largely related to vegetation stress, and have been included in the "Vegetation-Climate Factors" topic.

Respondents were only asked to answer the survey questions for metrics associated with their self-identified expertise(s). Consequently, not every metric was reviewed by the same number of respondents, and not every metric received the same number of ratings.

Ratings of usefulness for measuring progress towards the goals and ratings of feasibility, understandability, and sensitivity were all placed on a scale of 1 to 5, where 1 was the lowest value and 5 the highest. See Appendix A for exact survey language.

To summarize respondents' opinions about the regional relevance of each metric, we counted the number of ratings received by that particular metric, and then calculated the proportion of those ratings that considered the metric to be relevant to each region.

Results and Discussion

We summarize the disciplinary expertise of our survey respondents, the high-level results of each round of the survey, and metrics with particular importance for resilience goals, attributes, and regional relevance. Detailed results on metrics from each survey topic area are given in Appendix B and the full table of average ratings is available at the Environmental Data Initiative archive for this project.[2]

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[1] Manley, Patricia N.; Povak, Nicholas A.; Wilson, Kristen N.; Fairweather, Mary Lou; Griffey, Vivian; Long, Linda L. 2023. Blueprint for resilience: the Tahoe-Central Sierra Initiative. Gen. Tech. Rep. PSW-GTR-277. Albany, CA:U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 94 p. https://doi.org/10.2737/PSW-GTR-277.

[2] Eitzel, M.V., J. Battles, J. Smith, and S. Ostoja. 2024. California Wildfire Resilience Core Metrics Rating Process and Results ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/f559ba73136f51995f712320717e9548 (Accessed 2024-04-09).

Disciplinary Expertise

There were 38 respondents to the Round 1 survey, covering a range of different disciplinary expertise (Figure 3). The least represented disciplinary area was Hydrology/Watersheds; only 4 respondents indicated it as an area of their expertise. The disciplinary areas with the strongest representation were Vegetation Ecology, Ecosystem Management, and Fire Ecology. There were 38 respondents to the Round 2 survey (not necessarily the same individuals as in Round 1). Similar to Round 1, there were fewer respondents with expertise in hydrology and more respondents with expertise in vegetation and fire ecology, and management (Figure 4).

Figure 3: Disciplinary balance of Round 1 respondents (some respondents may have identified more than one disciplinary area of expertise; see Table 2 for definitions)

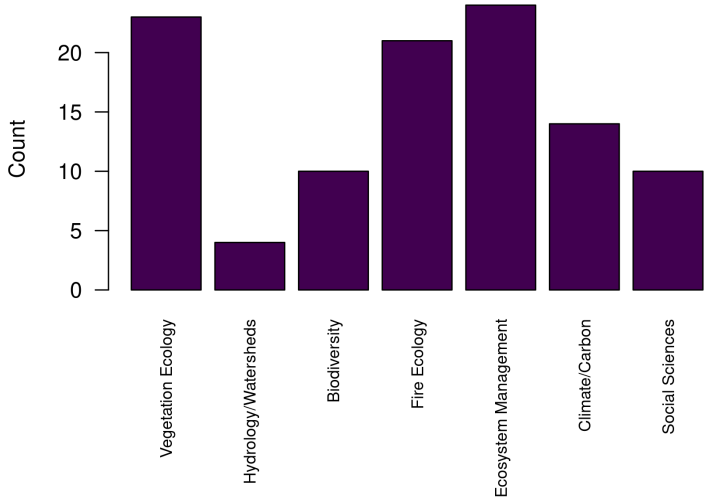
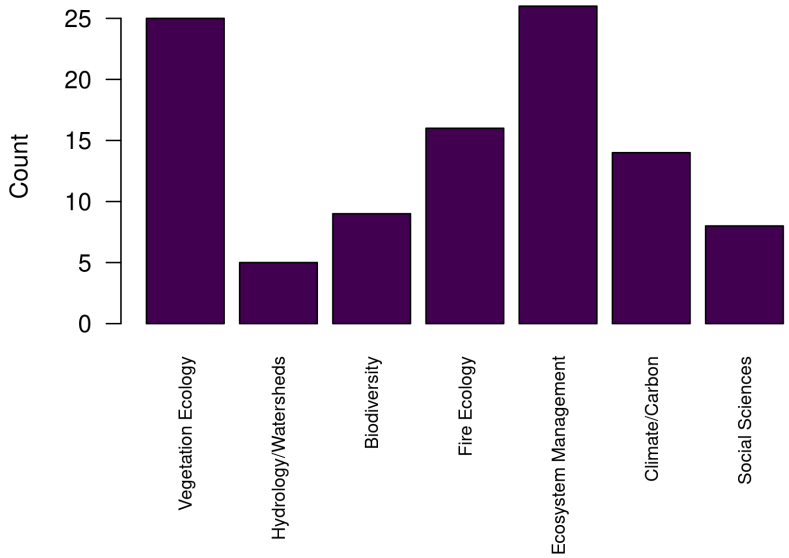


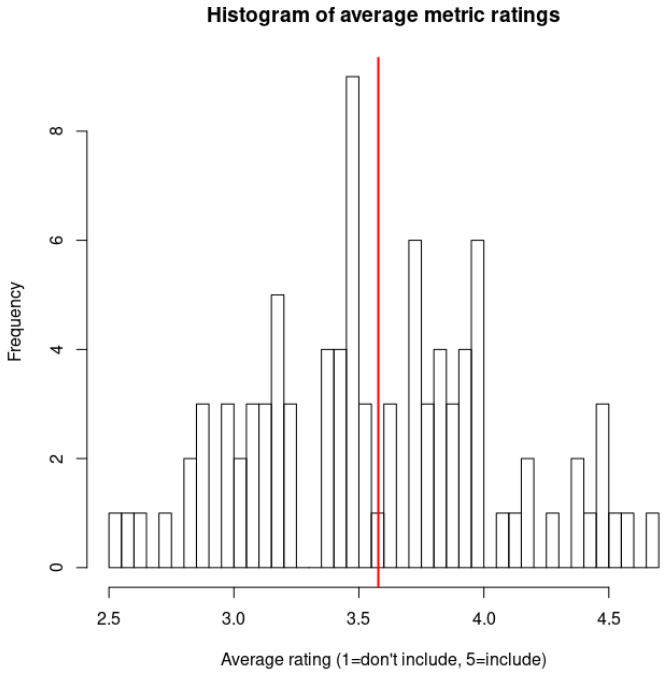
Figure 4: Disciplinary balance of Round 2 respondents (some respondents may have identified more than one disciplinary area of expertise; see Table 2 for definitions)



Round 1 Survey Results and Discussion

- Respondents generally agreed on criteria for core metrics. Core metrics should:
    - Be feasible to re-measure periodically using consistent, validated methods (ideally peer-reviewed)
    - Be relatively easy to understand and explain to non-scientific audiences
    - Be able to be reasonably aggregated from local scales to a statewide scale
    - Be able to capture a range of variation necessary for demonstrating changes in resilience
    - Be relevant to a range of both ecological and social values
    - Not be overly redundant/correlated with each other
- Respondents identified 10 metrics not worth including (with an average rating below 3, Fig. 5) in the Round 2 Survey.
- Respondents proposed 40 metrics not included in the Regional Resource Kit as potential valuable core metrics. However, the availability of these suggested metrics varied (see Appendix C for metric definitions and availability of suggested metrics).
- Respondents identified important considerations for selecting core reporting metrics:
    - The intended use of core metrics (e.g., planning for management actions, reporting on progress to a goal, tracking trends, or evaluating impact of activities) must be clearly specified
    - Metric ratings should be specific to a clearly defined resilience goal, as different metrics could be better suited for reporting on different goals
    - To use metrics for reporting on progress toward a resilience goal, the user must also define target ranges or threshold values that indicate a “good” condition.
    - Different ecosystems may require different metrics

Figure 5: Average Round 1 ratings for Regional Resource Kit Metrics (red line = Mean value).



Round 2 Survey Results and Discussion

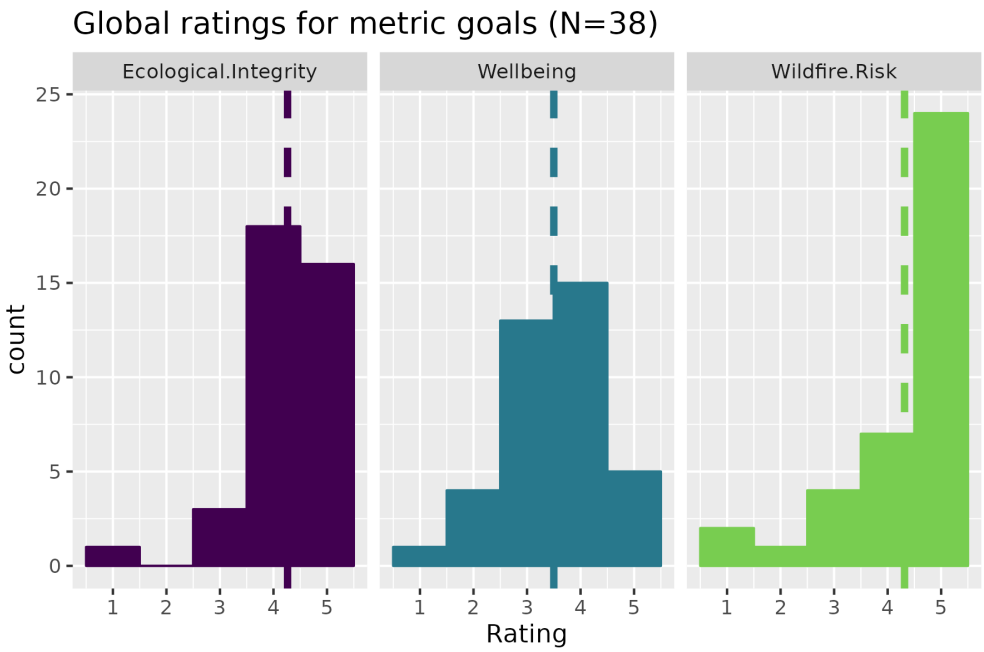
During the Round 2 survey, metrics were reviewed and rated by at least 3 and as many as 27 respondents.

The survey results indicated:

- Out of 115 metrics, 66 were rated highly useful (average rating of greater than 4 out of 5) for reporting on progress toward one or more of the three resilience goals.
- Some metrics (13) were rated highly useful for two of three goals, but only one metric (***probability of high severity fire***) was rated highly useful for all three goals.
- There are topical clusters in the "highly useful" metrics.
- In Round 1, respondents had the option to propose novel metrics to include in the list of candidate metrics reviewed in Round 2. Some of these novel metrics were highly rated in Round 2.

In general (not when considering any particular metric), respondents rated reducing wildfire risk as the most important resilience goal (mean 4.3, median 5), followed closely by ecological integrity (mean 4.3, median 4); social/cultural wellbeing was rated as more important (mean 3.5, median 4) than neutral (3 out 5) but lower than the others (Figure 6). This result may reflect the disciplinary balance of our survey respondents, and/or the urgency around wildfire risk.

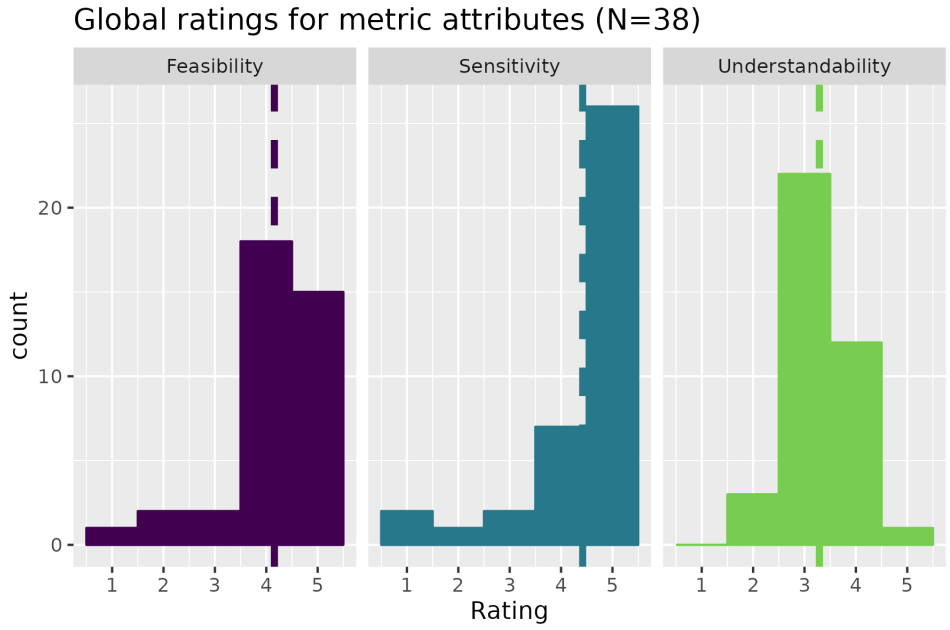
Figure 6: Ratings for different resilience goals as a whole (not considering a particular metric); averages shown by the dashed lines.



In general (not considering any particular metric), respondents rated sensitivity as most important (mean 4.4, median 5), followed closely by feasibility (mean 4.1, median 4);

understandability (mean 3.2, median 3) was slightly more important than neutral (Figure 7). This result may reflect the scientific orientations of our survey respondents.

Figure 7: Ratings for different metric attributes as a whole (not considering a particular metric); averages shown by the dashed lines.



For all 115 metrics, we calculated the average rating for each goal and each attribute. Figure 8 shows the distributions of the scores for all the metrics. Many, but not all, metrics were not considered useful for measuring progress towards supporting sociocultural wellbeing. Generally, more metrics were rated highly as useful for measuring progress towards goals of improving ecological integrity and reducing wildfire risk. Most of the candidate metrics did not have high attribute ratings, even though they were considered useful for measuring progress towards goals. Few metrics scored above a 4 in these categories, especially Sensitivity.

The average rating for each metric's usefulness for measuring progress towards each of the three resilience goals are shown in Figure 9. Some metrics were rated highly for two of three resilience goals; for example, the points clustered in the upper right reflect metrics that were rated highly useful for both ecological integrity and wildfire risk goals. Similarly, the large, light points at the top-left of the graph reflect metrics that were rated highly useful for both wildfire risk and social/cultural wellbeing goals. However, ratings are typically not high for all three (i.e., there are not many large, light points in the upper right, though there are some points with moderate wellbeing scores in that area of the plot).

Figure 8: Distributions of average ratings for all metrics, for the three resilience goals: A) Wildfire Risk, B) Ecological Integrity, C) Wellbeing; and the three attributes D) Feasibility, E) Sensitivity, and F) Understandability.

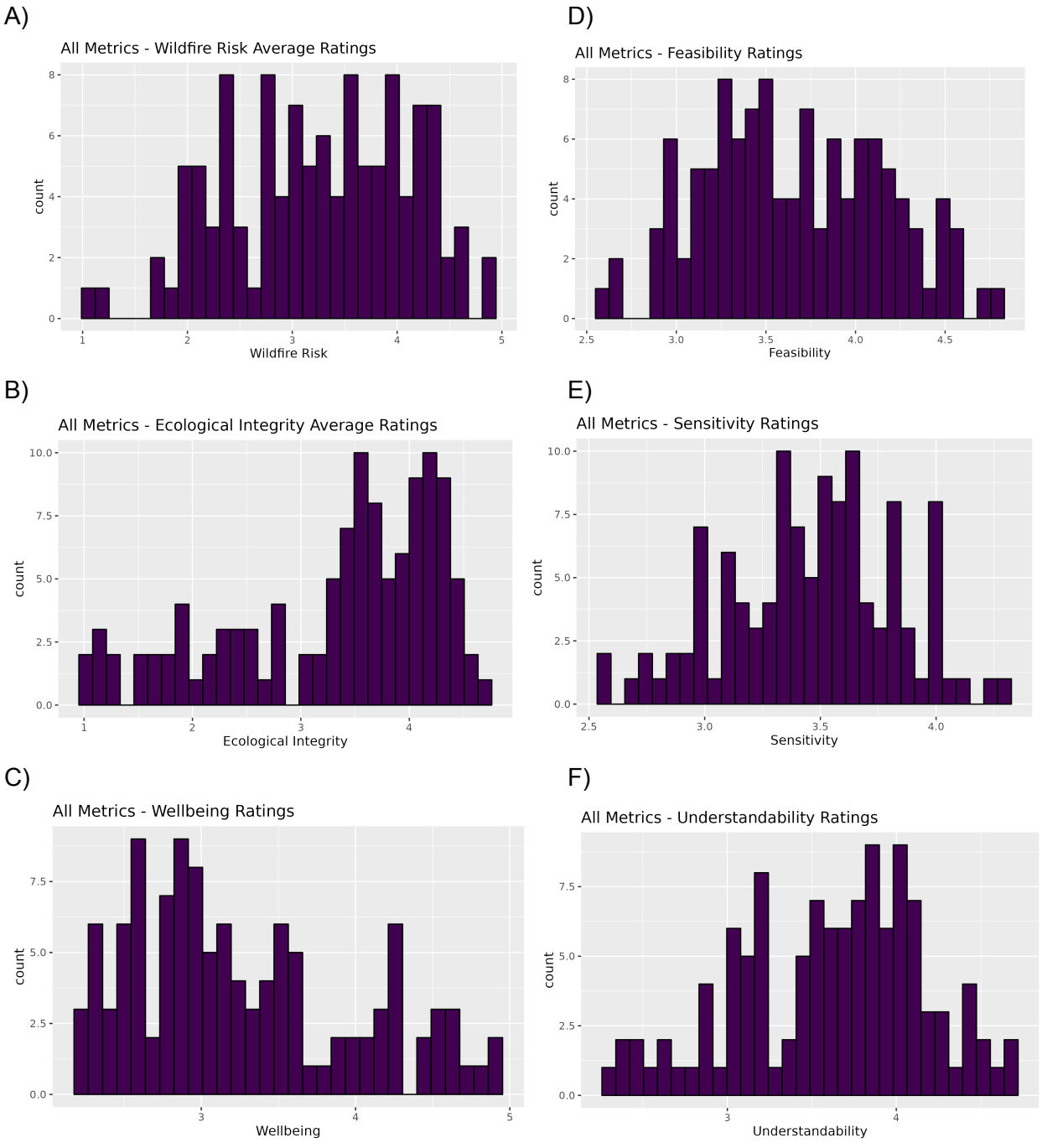
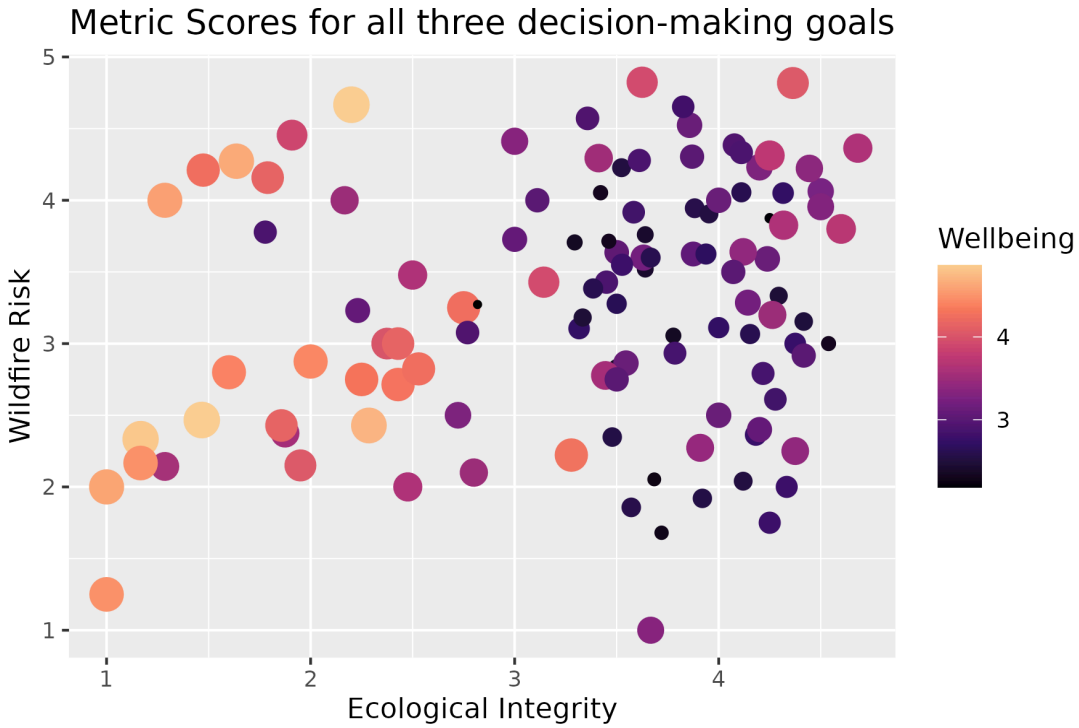


Figure 9: Distribution of average ratings on all three goals (x = Ecological Integrity, y = Wildfire Risk, and lighter point color/larger size = higher Wellbeing) for all metrics.



Specific Metric Results and Discussion

Below we share specific metrics that emerged as highly useful for one or more resilience goal, which metrics had desirable attributes, and also summarize the metrics' regional relevance.

Resilience Goals

Probability of high severity fire was the only metric that was rated highly useful (with an average score greater than 4 out of 5) for reducing wildfire risk, improving ecological integrity, and supporting social and cultural wellbeing. An additional 13 metrics (Table 3) were rated highly useful for at least two of those three goals, and 66 of the 115 metrics in the survey were rated highly useful for one of the three goals (See Appendix B).

Some top-rated metrics are already present in the RRKs, for example ***Probability of High Severity Fire, Damage Potential in the Wildland-Urban Interface (WUI), Standing Dead and Ladder Fuels, Vegetative Stress During Extreme Drought, Tree Mortality,*** and ***Shrub Resilience***. However, our survey included ratings of proposed metrics from survey respondents. Some proposed metrics exist but are not in the RRKS (for example, ***Cal EnviroScreen score*** and ***Areas of Low Potential Shrub Regeneration***), while others are novel, such as ***Health Outcomes Related to Air Quality/Smoke*** and ***Insurance Availability/Price.***

Table 3. Metrics that were rated highly useful (average score greater than 4 out of 5) for at least two of the three goals, and single metric was rated highly useful for all three (bold).

	Reducing wildfire risk	Improving ecological integrity	Supporting social and cultural wellbeing
Probability of High Severity Fire	X	X	X
Tree Density	X	X	
Proportion of Max Stand Density Index	X	X	
Vegetative Stress During Extreme Drought	X	X	
Tree Mortality	X	X	
Time Since Last Fire	X	X	
Mean Percent FRID since 1970	X	X	
FRID Condition Class for Departure	X	X	
Recent Fire Severity	X	X	
Duration of effect of management action	X	X	
Evacuation capacity	X		X
Damage Potential in WUI	X		X
Structure Exposure Score In WUI	X		X
Firewise approved communities or communities with Community Wildfire Protection Plans	X		X

Metrics serving the resilience goal of Supporting Sociocultural Wellbeing are an important growth area: many metrics were suggested by survey respondents in Round 1, and many of these proposed metrics received high ratings in Round 2. Community readiness for fire, environmental justice and health impacts of both fire and of treatments, and measures of economic opportunity were all topics that were lacking in the Regional Resource Kits and are therefore an area of future work for both the Kits and for core metrics representing progress on resilience in these areas.

Metric Attributes

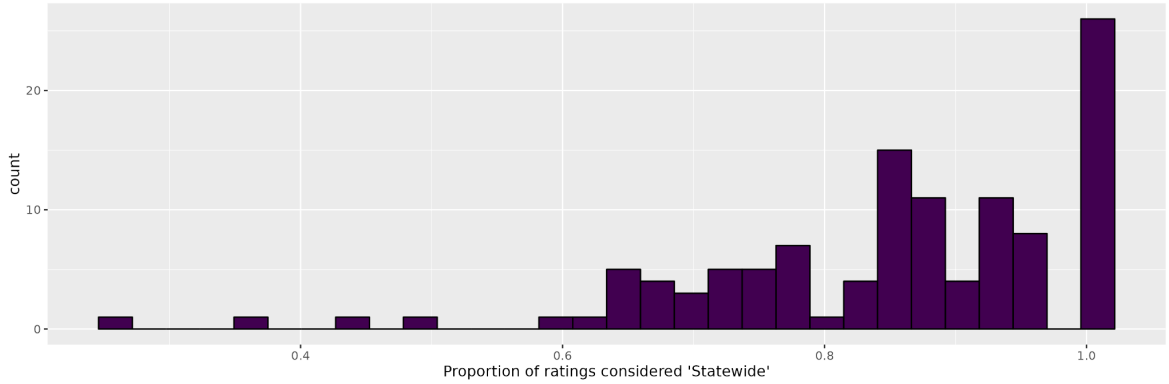
In addition to being useful for reporting on progress towards goals, a core metric can only be a viable choice if it is realistic to re-measure (Feasibility) and if it is sensitive enough to management action to capture changes in resilience driven by that action (Sensitivity). A secondarily important attribute is how easy the metric is to explain to a variety of audiences (Understandability). Feasibility and Sensitivity were considered more important attributes for core metrics than Understandability by our survey respondents. The only metrics that were rated highly (average ratings of greater than 4 out of 5) for both *Sensitivity* and *Feasibility* were ***Repeated High Severity Fire*** (a novel proposed metric), ***Tree Mortality*** and ***Density (Trees Per Acre)***. These three metrics were also rated as highly *Understandable*, and as highly useful for measuring progress towards goals of reducing wildfire risk and improving ecological integrity. On the other hand, many of the 66 “highly useful” metrics which had an average score of greater than 4 out of 5 on one of the goals (listed in Tables B1-B14) did not necessarily rate highly for *Sensitivity* and *Feasibility*. In fact, only 41 of the metrics included in the survey had an average rating greater than 4 out of 5 for any of the three attributes.

Regional Relevance

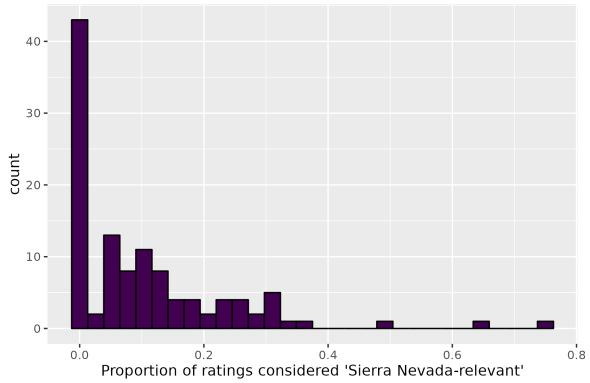
Survey respondents were asked to indicate for which of the Task Force regions a candidate metric was relevant (Figure 10).

Figure 10: Histograms of regional relevance to A) statewide concerns, B) the Sierra Nevada region, C) the Southern California region, D) the Central California Region, E) the Northern California Region.

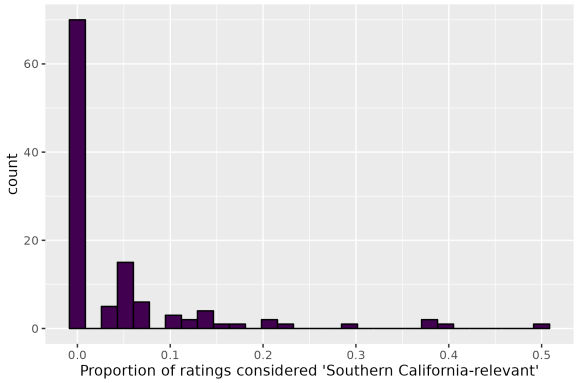
A) Statewide-Relevant Metrics



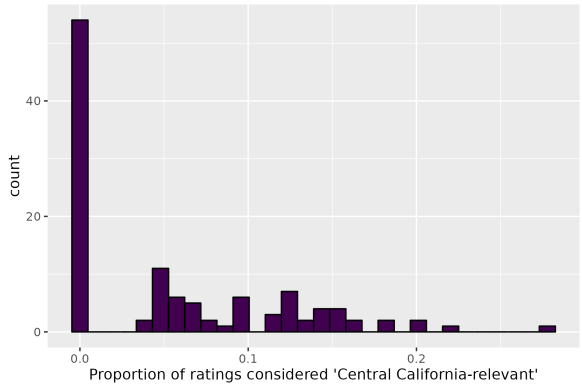
B) Sierra Nevada-Relevant Metrics



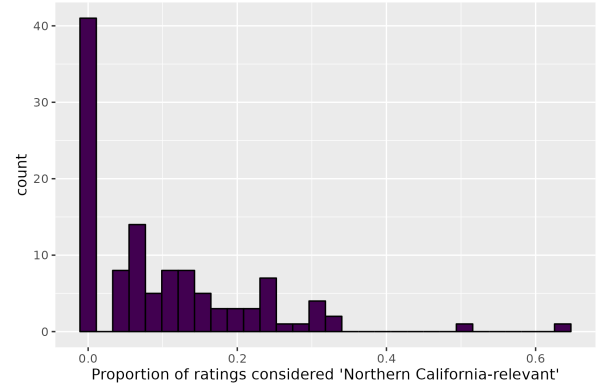
C) Southern California-Relevant Metrics



D) Central California-Relevant Metrics



E) Northern California-Relevant Metrics



26 metrics were considered to be statewide-applicable by all respondents who rated them; for nearly all 115 metrics, at least half of the respondents considered them to be applicable statewide. However, there was far less consensus on regional suitability for each metric. Of the 66 metrics rated highly useful for one of the three goals (Tables B1-14), 17 of them received consensus regarding statewide relevance from all respondents who rated them.

Future Work

We have demonstrated a method for obtaining rapid interdisciplinary expert opinion on core reporting metrics for tracking resilience. The surveys have been summarized and shared with the Task Force staff (in both this report and in slide decks and other communications), and based on these results, SAP staff have given feedback on the Task Force's proposed set of metrics which has supported their decision making process in revising the list.

Some considerations for proceeding with selection of core metrics arose through this process. First, metrics selected (and targeted desirable ranges for these metrics) need to take into account the differences between different ecosystems throughout the state. For example, a desired range for ***Probability of High Severity Fire*** that reflects a resilient ecosystem could be quite different between a forested landscape (where high severity fire can result in the inability to recover back to a forested state) and a shrubland (where high severity fire may be recovered from so a high probability does not equate to low resilience). Conversely, a resilient fire return interval for these two ecosystems could be quite different.

Second, the tradeoff between the logistical aspects of the metrics (feasibility of remeasurement, ease of explanation) with their scientific value (sensitivity to the process of interest) needs to be evaluated with the target audience in mind. This is not a scientific question, so we do not make a claim as to how the tradeoff should be made, but raise the issue that it should be done transparently. If understandability is key, in order to demonstrate value to legislators and the public, care must be taken in weighing the potential loss of scientific accuracy with loss of ability to communicate.

Third, many metrics can address resilience across multiple topic areas and therefore framing this overlap carefully is important when determining how to track progress towards resilience goals. With feedback from the Task Force staff, we chose three broad overlapping goals but there are other ways to frame resilience in different dimensions. The topic areas we used for grouping the metrics in the report are largely for convenience and do not reflect group consensus. These groupings could be revisited in further work.

Finally, we suggest that this process can be repeated as needed. For example, new metrics or methods of calculating them may be developed, and the full suite of potential metrics should be re-evaluated to select the best core metrics taking this new information into account. In addition, different purposes for the metrics could call for another round of expert review: core metrics appropriate for planning, monitoring, or project evaluation at different spatial or organizational scales could be quite different from these metrics intended for statewide or regional reporting.

Another situation to re-evaluate the core metrics could be to target them for a different audience, for example land managers rather than legislators. Similarly, a different group of respondents could be surveyed in order to tap into a different set of expertise to evaluate a set of core metrics. Finally, if a different set of resilience goals is defined, the set of core metrics could be re-evaluated.

Appendix A: Survey Language

Below, we reproduce the text shown to respondents in our Round 1 and Round 2 surveys, omitting repetitive text and tables for readability. See the Environmental Data Initiative archive for this project for the complete text of each survey, as well as the complete metric dictionaries cited in the survey questions.[3] For the "Metric Cheat Sheet" mentioned in the survey questions, see Appendix B. Note that the survey respondents accessed these materials during the survey from the Google Drive links, but we have included them here and in the archive to ensure persistent access.

Round 1 Survey

Assessing Potential Core Metrics for the Wildfire and Forest Resilience Task Force - Round 1

The California Wildfire and Forest Resilience Task Forces' Regional Resource Kits include an extensive set of metrics for assessing landscape conditions in each of the four Task Force regions. These metrics are intended to facilitate assessing and planning landscape treatment projects that meet an array of socio-ecological resilience objectives.

However, there is an increasing need to identify a subset of these metrics that can provide a consistent and concise method for decisionmakers to track progress toward achieving state goals related to wildfire risk abatement and socioecological resilience. Possible uses for this "core" subset of metrics include:

- A dashboard-style statewide and/or regional tracker of overall progress towards greater resilience
- Incorporation into decision support tools for prioritization of future management actions
- In combination with the Interagency Treatment tracking tool and appropriate analyses, changes in these metrics could be attributed to management actions in order to predict or assess efficacy

The Science Advisory Panel staff scientist is organizing input from experts on which metrics are most appropriate for this set of "core metrics." Both Panel members and non-Panel experts will be invited to respond. We appreciate your participation in this important project.
Please provide your name:

In this round 1 of the survey, we seek to (1) identify any metrics that should be considered for the core subset and are not included in the regional resource kits and (2) eliminate metrics which are in the kits, but do not have the following characteristics:

- Feasible to re-measure periodically using consistent methods
- Relatively easy to understand and explain to non-scientific audiences

[3] Eitzel, M.V., J. Battles, J. Smith, and S. Ostoja. 2024. California Wildfire Resilience Core Metrics Rating Process and Results ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/f559ba73136f51995f712320717e9548 (Accessed 2024-04-09).

- Able to be reasonably aggregated from local scales to statewide scales
- Not overly redundant/correlated with each other
- Able to capture the appropriate range of variation to demonstrate changes in resilience

What other characteristics should the set of "core" metrics have, if any?

Please indicate your expertise from the list below – select all that apply. We will ask you to review metrics only within your areas of expertise; your response(s) below will filter the suite of subsequent metrics you are shown.

- Vegetation Ecology - Including forest ecosystems, chaparral ecosystems, grassland ecosystems, urban ecosystems, plant physiology, and other vegetation-related topics
- Fire Ecology - Including fuels and fire behavior modeling, fire dynamics and fire ecology
- Biodiversity - Including conservation biology, wildlife ecology, threatened and endangered species, and other wildlife related topics
- Hydrology and Watershed Services - Including watershed processes, hydrological systems modeling, and other water related topics
- Ecosystem management - Including forest, shrublands, and/or grasslands management, ecosystem services, community ecology, reforestation or restoration, and the built environment
- Climate science - Including climate adaptation science, nature based solutions, atmospheric, climate, and emissions modeling, carbon accounting and modeling
- Social Sciences - Including economics, sociology, community development/engagement, Native American studies and other disciplines and topics relevant to socio-ecological resilience, for example socioeconomic expertise related to disadvantaged communities, recreation uses, and rural livelihoods

Which of the following metrics could be worth including as a core metric for planning and evaluating efficacy of landscape treatments? You may briefly explain your reasoning for your answers in the text box below each metric (e.g., it's not feasible to remeasure this metric).

Note: You do not need to weigh the value of these metrics against each other. The purpose is only to eliminate metrics that are clearly not appropriate for inclusion. In a subsequent survey (round 2) we will ask you to rate the metrics against each other.

Brief metric definitions are available here:
https://docs.google.com/document/d/1ad3bJYNHSQnbyegYP9sABdnuld5c2RiKjGCDGduWheU/edit
Full definitions from Regional Resource Kit Metric Dictionaries are available here:
https://drive.google.com/file/d/1p9P0b6NcYxvuvODtv6EOnVsZtgnv75Ra/view?usp=sharing

Remember, core metrics are:

- Feasible to re-measure periodically using consistent methods
- Relatively easy to understand and explain to non-scientific audiences

- Able to be reasonably aggregated from local scales to statewide scales
- Not overly redundant/correlated with each other
- Able to capture the appropriate range of variation to demonstrate changes in resilience

(Table listing metrics and asking respondents to rate them from 1 to 5, with 1 - Not worth including and 5 - Definitely worth including.) See the Environmental Data Initiative archive[4] for this project for the list of metrics that were rated.

Please suggest any additional metrics that were missing from the list you reviewed and meet our criteria (copied below). Any additions that meet these criteria will be included in the subsequent survey.

Remember, core metrics are:

- Feasible to re-measure periodically using consistent methods
- Relatively easy to understand and explain to non-scientific audiences
- Able to be reasonably aggregated from local scales to statewide scales
- Not overly redundant/correlated with each other
- Able to capture the appropriate range of variation to demonstrate changes in resilience

How many metrics would you like to suggest? (enter "0" if you don't have any to suggest)

▼ 0 ... 10

Additional Metric X:
Name of Metric _____
Description of Metric _____
Data Sources _____
Measurement/Analysis Methods _____

(The survey looped through up to 10 additional metrics.)

[4] Eitzel, M.V., J. Battles, J. Smith, and S. Ostoja. 2024. California Wildfire Resilience Core Metrics Rating Process and Results ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/f559ba73136f51995f712320717e9548 (Accessed 2024-04-09).

Round 2 Survey

Assessing Potential Core Metrics for the Wildfire and Forest Resilience Task Force - Round 2 - Rating

The California Wildfire and Forest Resilience Task Forces' Regional Resource Kits include an extensive set of metrics for assessing landscape conditions in each of the four Task Force regions. These metrics are intended to facilitate assessing and planning landscape treatment projects that meet an array of socio-ecological resilience objectives. However, there is **an increasing need to identify a subset of these metrics** that can provide a consistent and concise method for decisionmakers to track progress toward achieving state goals related to wildfire risk abatement and socioecological resilience.

In Round 1 of our survey process, the Science Advisory Panel and other experts reviewed a list of candidate metrics sourced from the regional resource kits. Survey respondents also suggested missing metrics, and commented on important attributes of core metrics. Round 1 raised the important question "What are these core metrics going to be used for?"

Therefore, in Round 2 of our survey process, we will focus on one specific use for a set of key or "core" metrics: **evaluation of progress towards resilience at the regional or statewide level**. This survey will ask you to rate the appropriateness of metrics for this use. We envision that core metrics may be used in statewide reporting, such as updating the Task Force's Action Plan. Consequently, core metrics should be able to be aggregated or scaled up to the statewide or regional (as defined by the Task Force) level.

Please provide your name:

Before we ask you to rate individual metrics, we would like your opinion on the relative importance of the key "core metric attributes" and of the goals for which these metrics are measuring progress towards.

We will use these responses to help inform and break "ties" for metrics that rated similarly.

Key Attributes of Core Metrics

A) Feasibility of re-measurement - this attribute considers the feasibility of data access, analysis, and/or ability to remeasure the metric as-needed (ideally annually but at least every 5 years).

B) Ease of explanation – this attribute considers how challenging a metric is to understand and explain to managers, policymakers, or members of the public.

C) Sensitivity to the process of interest – this attribute considers how well the metric detects change in the process of interest.

Please rate, in your opinion, the relative importance of these three attributes of a core metric *(1=Not Important, 5=Most Important)*

(The survey then gave a table with the three attributes)

Broad goals:

We will ask you to rate the usefulness of each metric for three broad decision-making goals:

A) Reducing Wildfire Risk - focused on community protection and safety, especially in and around the Wildland-Urban Interface (WUI)

B) Improving Ecological integrity - focused on reducing large high-severity wildfires that compromise, for example (but not limited to) biodiversity, watershed services, carbon stocks, etc
C) Supporting rural livelihoods, public health, and cultural wellbeing - focused on forest product/recreation economies, household financial stability, benefits or harm associated with wildfire and vegetation management actions, environmental justice concerns, and other social and cultural benefits

Please rate, in your opinion, the relative importance of these three goals *(1=Not Important, 5=Most Important)*

(The survey then gave a table with the three goals)

Please indicate your expertise from the list below – select all that apply. We will ask you to review metrics only within your areas of expertise; your response(s) below will filter the suite of subsequent metrics you are shown.

- Vegetation Ecology - Including forest ecosystems, chaparral ecosystems, grassland ecosystems, urban ecosystems, plant physiology, and/or other vegetation-related topics
- Fire Ecology - Including fuels and fire behavior modeling, fire dynamics and/or fire ecology
- Biodiversity - Including conservation biology, wildlife ecology, threatened and endangered species, and/or other wildlife related topics
- Hydrology and Watershed Sciences - Including watershed processes, hydrological systems modeling, and/or other water related topics
- Ecosystem management - Including forest, shrublands, and/or grasslands management, ecosystem services, community ecology, reforestation or restoration, and/or the built environment
- Climate science - Including climate adaptation science, nature based solutions, atmospheric, climate, and emissions modeling, carbon accounting and modeling

- Social Sciences - Including economics, sociology, community development/engagement, Native American studies and/or other disciplines and topics relevant to socio-ecological resilience, for example socioeconomic expertise related to disadvantaged communities, recreation uses, and rural livelihoods

Rating Metrics

Round 1 of our survey process removed some metrics from consideration and added others. In this survey, Round 2, you will be asked to rate metrics on the strength of their attributes, and usefulness for evaluating progress towards different goals. You will be able to skip any metrics you don't feel comfortable rating.

The metrics within your selected expertise(s) are grouped by topic for convenience. Although you will be shown multiple topical groupings of metrics, please consider, and base your ratings relative to, all of the metrics you are shown.

Please remember that the goal of this project is to identify 20 – 30 core metrics across all disciplines and associated topics.

Topic: X (The survey had 14 different topics, with the following text repeated for each)
For each of the following metrics, please rate your response to the following questions. If you prefer not to rate a given metric please check the box marked "Skip this Metric." For any metrics you do rate, please provide a response for all questions (i.e., 1a-c, 2, and 3a-c) . Please use the empty text box below the metric's name to note caveats or share other comments about your response.

Goals:
1a) How useful the metric is for assessing wildfire risk? *1 (less useful) to 5 (extremely useful).*
1b) How useful the metric is for assessing ecological integrity? *1 (less useful) to 5 (extremely useful).*
1c) How useful the metric is for assessing livelihoods, health, and wellbeing? *1 (less useful) to 5 (extremely useful).*

Geographical Focus:
2) For which regions is the metric appropriate? Please include a region even if the metric is appropriate for some, but not all, major ecotypes in the region. Check all that apply. If you are unsure, use your best judgment.

NC=Northern California, SC=Southern California, SN=Sierra Nevada, CC= Central Coast

Characteristics:
3a) How feasible is it to repeat measurements of this metric? *(1=Not feasible, 5=Very feasible)*
3b) How easy is it to explain this metric? *(1=Hard to explain, 5=Easy to explain)*

3c) How sensitive is this metric to detecting change in the process of interest? *(1=Not very sensitive, 5=Very sensitive)*

Brief metric definitions, including descriptions of suggested metrics:
https://docs.google.com/document/d/1ad3bJYNHSQnbyegYP9sABdnuld5c2RiKjGCDGduWheU/edit
Full definitions for Regional Resource Kit Metrics:
https://drive.google.com/file/d/1p9P0b6NcYxvuvODtv6EOnVsZtgnv75Ra/view?usp=sharing

(For each topic, the survey had a table showing each metric within that topic as a row in a table with columns for each of the rating questions listed above. See the Environmental Data Initiative archive[5] for this project for the list of metrics that were rated and the topics they were grouped under.)

Thank you for your time and participation. Please feel free to use the back buttons to return to earlier pages and adjust ratings. Remember that we are trying to identify a small subset of metrics **to be used at a statewide level for tracking progress towards greater resilience**, which necessitates removing many valuable metrics from consideration.

To submit your responses, click "Submit Survey."

[5] Eitzel, M.V., J. Battles, J. Smith, and S. Ostoja. 2024. California Wildfire Resilience Core Metrics Rating Process and Results ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/f559ba73136f51995f712320717e9548 (Accessed 2024-04-09).

Appendix B: Detailed Metrics Results by Topic

Below are detailed results for the 72 metrics with high average ratings (greater than or equal to 4 out of 5) for usefulness for measuring progress towards one of the three resilience goals (*Wildfire Risk*, *Ecological Integrity*, and/or *Wellbeing*). Note that the main text highlights only the metrics that are rated greater than 4 out of 5; we include additional metrics here to provide more context for which metrics may have been on the threshold of being rated "highly useful." We group the metrics by their topics from the survey (created by SAP Staff for convenience when viewing the metrics). We note which metrics are not currently in the Regional Resource Kits (version 1) and are "New" metrics that were suggested in the Round 1 surveys. We have highlighted metric names in ***bold italics*** for better navigability of the document. When a metric informs more than one topic, it is mentioned more than once, in each relevant topic. For several topics, there is also general topical overlap, e.g., "Wildfire History," "Wildfire Hazard," and "Wildfire Risk," and we have referred the reader to the related topic area where relevant. The full list of average ratings for all 115 metrics, and histograms of the individual ratings and qualitative comments from survey respondents for each metric, are included in the related Environmental Data Initiative archive.[6] Narrative summaries for each topic area are based on the qualitative comments of individual respondents as well as the quantitative average ratings.

Note that some topic areas or Pillars/Elements may be entirely missing from the lists in Appendix B; this reflects that no metrics from those topics in the RRKs or suggested metrics had average ratings greater than 4 out of 5. For example, Metrics focused purely on water are largely missing from the RRKs and those that were considered had average ratings below 4 out of 5.

Wildfire Risk

Table B1: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Score 1			**Attribute Scores[2]**			**Number of ratings[3]**			**Combined scores[4]**	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Probability of High Severity Fire	No	**4.82**	**4.36**	**4.05**	3.76	3.90	3.81	22	22	22	53.56	45.33
Damage Potential in WUI	No	**4.67**	2.20	**4.87**	3.92	3.71	3.50	15	15	15	46.55	44.00
Probability of Ignition From Humans or Lightning	No	**4.41**	3.00	3.35	3.41	**4.12**	3.71	17	17	17	43.57	44.11

[6] Eitzel, M.V., J. Battles, J. Smith, and S. Ostoja. 2024. California Wildfire Resilience Core Metrics Rating Process and Results ver 1. Environmental Data Initiative. https://doi.org/10.6073/pasta/f559ba73136f51995f712320717e9548 (Accessed 2024-04-09).

		Goal Score 1			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Annual Burn Probability	No	**4.29**	3.41	3.53	3.88	3.19	3.63	17	17	17	45.43	42.62
Structure Exposure Score in WUI	No	**4.27**	1.64	**4.64**	3.70	3.20	**4.00**	11	11	11	41.64	43.59
Recent Fire Severity	No	**4.22**	**4.44**	3.39	**4.50**	3.94	**4.00**	18	18	18	49.03	49.37
Probability of Moderate Severity Fire	No	**4.00**	**4.00**	3.13	3.75	3.53	3.40	16	16	16	45.25	42.25
Ratio of High to Low/ Moderate Severity Wildfire	Yes	3.80	**4.60**	3.70	3.90	3.20	3.60	10	10	10	48.96	42.66

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Probability of High Severity Fire is by far the best performer across the survey results: it has scores above 4 for all three resilience goals. ***Recent Fire Severity***, ***Probability of Moderate Severity fire*** (both in the RRKs), and ***Ratio of High to Low/Moderate Severity Fire*** (a proposed metric, not a pre-existing one) had good ratings for *Ecological Integrity* but not necessarily for *Wildfire Risk*. ***Damage Potential in the Wildland Urban Interface*** **(WUI)** and ***Structure Exposure Score in the WUI*** both had good ratings for *Wellbeing* in addition to *Wildfire Risk*. ***Recent fire severity*** (which is technically an operational layer for planning in the RRKs) is also noted as being *Feasible* and *Sensitive*. The obvious winning metric on this topic is ***Probability of High Severity Fire***, but we note that what constitutes 'high severity' may vary by ecosystem/vegetation type. We also note that metrics in the "Community Wellbeing" topic may also relate to fire risk, including ***Insurance Availability/Price***, number and statewide coverage of ***Firewise Communities and Community Wildfire Protection Plans (CWPPs)***, and ***Community Domain: Educating/Preparing***.

Wildfire History

Table B2: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray. FRID= Fire Return Interval Departure

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
FRID Condition Class for Departure	No	**4.33**	**4.11**	2.89	**4.35**	3.41	**4.00**	18	18	18	46.34	47.01

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Fire Regime	Yes	**4.30**	3.87	3.00	**4.27**	3.83	3.43	23	23	23	45.57	45.54
Mean Percent FRID Since 1970	No	**4.06**	**4.11**	2.61	**4.33**	2.94	**4.00**	18	18	18	44.17	45.39
Shrub Resiliency	No	3.00	**4.54**	2.31	3.69	3.08	3.38	13	13	13	40.37	40.44

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Fire Return Interval Departure (FRID) Condition Class performs well within the "Wildfire history" topic, with higher ratings in both *Wildfire Risk* and *Ecological Integrity*, as well as *Feasibility* and *Sensitivity*, though it is not very *Understandable*. ***Fire Regime*** is a proposed metric that is not yet well developed or defined, but may help to account both for historical ranges of variation and differences in different ecosystems. ***Mean Percent Departure in Fire Return Interval*** had similar ratings to ***FRID Condition Class***, but survey respondents raised the question of 'why 1970 as a reference year'? ***Shrub Resiliency*** performs well for *Ecological Integrity* though it will necessarily be shrubland-specific. If the ultimate strategy to account for regional/ecosystem variation involves assembling multiple metrics on similar topics that are focused on specific ecosystems, this metric may be a good choice for shrublands, alongside metrics more appropriate for forested areas.

Wildfire Hazard

Table B3: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Standing Dead and Ladder Fuels	No	**4.65**	3.83	2.83	3.52	3.78	3.96	23	23	23	46.28	44.58
Total Fuel Exposed to Fire	No	**4.57**	3.36	2.93	3.50	3.50	3.86	14	14	14	44.29	43.12
Total Dead Down Fuels	No	**4.52**	3.86	3.14	3.52	3.95	3.85	21	21	21	46.97	44.67
Heavy Fuels	No	**4.28**	3.61	2.89	3.33	3.61	3.50	18	18	18	43.97	41.21
Wildfire Hazard Potential	No	**4.82**	3.63	3.94	3.80	3.75	3.69	17	16	16	50.05	44.44

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Time Since Last Fire	No	**4.23**	**4.20**	3.28	**4.72**	**4.48**	**4.00**	26	25	25	47.64	52.05
Repeated High Severity Fire	Yes	3.95	**4.50**	3.32	**4.76**	**4.33**	**4.14**	22	22	22	47.86	52.37

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

This topic includes four metrics regarding fuel loading (***Standing Dead and Ladder Fuels***, ***Total Fuel Exposed to Fire***, ***Total Dead and Down Fuels***, and ***Heavy Fuels***). Of these, ***Standing Dead and Ladder Fuels*** has the highest average rating for *Wildfire Risk*. Among the other metrics, ***Wildfire Hazard Potential*** has a very high rating for *Wildfire Risk*, on par with ***Probability of High Severity Fire***. ***Time Since Last Fire*** has good ratings for both *Wildfire Risk* and *Ecological Integrity*, as well as *Feasibility*, *Understandability*, and *Sensitivity*. The optimal return time, of course, will depend on the ecosystem in question. ***Repeated High Severity Fire*** is a novel metric that does not yet exist, but performs well for *Ecological Integrity*, as well as *Feasibility*, *Understandability*, and *Sensitivity*, but may also need to be calibrated differently for different ecosystems. This may be a metric worth considering when planning for future work.

Vegetation Structure & Composition

Table B4: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Areas of Low Potential Shrub Regeneration	Yes	3.15	**4.42**	2.50	3.50	3.67	3.25	13	12	12	41.19	40.98
Proportion of Max Stand Density Index	No	**4.05**	**4.32**	2.74	3.94	3.11	3.89	20	19	19	45.46	43.81
Risk of Tree Dieoff During a Drought	No	3.83	**4.32**	3.64	3.27	3.55	3.38	23	22	22	47.65	40.22
Seral Stage Distribution	No	3.33	**4.29**	2.47	3.12	2.82	3.31	18	17	17	41.34	36.90
Mature Forest Habitat	Yes	3.20	**4.26**	3.47	3.05	3.58	3.32	20	19	19	44.14	39.12

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Fine Scale Heterogeneity Index	No	3.88	**4.25**	2.19	3.06	2.50	3.63	16	16	16	42.50	36.98
Cumulative Tree Cover Lost	No	3.59	**4.24**	3.14	**4.24**	**4.10**	**4.00**	22	21	21	44.57	48.78
Natural Conifer Regeneration	No	2.79	**4.22**	2.87	3.00	3.57	3.61	24	23	23	40.07	40.16
Shrub Post-fire Regeneration Strategies	Yes	3.07	**4.15**	2.62	3.31	3.00	3.38	15	13	13	40.10	38.59
Large Tree Density	No	3.64	**4.12**	3.40	3.96	**4.40**	3.80	25	25	25	45.17	47.74
Density (Trees Per Acre)	No	**4.38**	**4.08**	2.92	**4.19**	**4.27**	**4.08**	26	26	25	46.52	49.50
Shrub Cover	No	**4.23**	3.52	2.52	**4.00**	3.95	3.50	22	21	21	42.10	45.11

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

This topic contains by far the most metrics, reflecting the focus of research in general and the contents of the Regional Resource Kits in particular. Both forest and shrubland vegetation composition and structure metrics are included in this group, and most metrics perform well for *Ecological Integrity*, with a few that rate highly for *Wildfire Risk*. Because there are many to choose from, we highlight the top two, which cover both shrubland and forest: 1) ***Areas of Low Potential Shrub Regeneration***, which is a shrub-related, novel metric which has been recently published, and 2) ***Proportion of Maximum Stand Density Index (SDI)***, which is a tree-related metric which reflects the degree of tree competition in a particular site. In contrast, ***Trees per acre*** or ***Cumulative Tree Cover Lost*** perform better on *Feasibility*, *Understandability*, and *Sensitivity* than ***Proportion of Max SDI***, but were less highly rated for *Ecological Integrity*. Considering the tradeoff between the logistics of the metric and its accuracy will be necessary when choosing core metrics; this choice will depend on the desired audience for the metrics.

Urban Canopy Cover is also vegetation structure/composition related, but it is less clear how this relates to wildfire resilience. ***Habitat Connectivity*** appeared in the “Biodiversity” topic, but is a vegetation structure/landscape modeling variable and could be relevant in this topic as well.

Vegetation-Climate Factors

Table B5: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Tree Mortality	No	**4.36**	**4.68**	3.64	**4.09**	**4.50**	**4.23**	22	22	22	51.52	50.50
Vegetative Stress During Extreme Drought	No	**4.06**	**4.50**	3.25	3.87	3.50	**4.00**	16	16	16	48.09	45.27
Meadow Sensitivity Index	No	3.00	**4.38**	2.75	**4.00**	2.63	3.63	8	8	8	41.22	41.29
Drought Sensitivity	No	3.50	**4.07**	3.00	3.29	3.07	3.79	14	14	14	42.96	40.50

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

None of the metrics related to water quality or quantity were rated above 4 out of 5 on any of the resilience goals; the most topically related were metrics regarding vegetation stress associated with drought and climate factors. Of these, ***Tree Mortality*** rated well on both *Wildfire Risk* and *Ecological Integrity*, as well as *Feasibility*, *Understandability*, and *Sensitivity*. Some background mortality may be healthy, so 'desired' ranges should be chosen carefully, and the metric is clearly forest-specific, but is otherwise a very high performer. ***Meadow Sensitivity Index*** is forest-specific, ***Drought Sensitivity*** is shrub-specific. See also the "Vegetation, Climate, and Biodiversity" topic.

Vegetation, Climate, and Biodiversity Interactions

Table B6: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Beetle Sensitivity	Yes	2.92	**4.42**	3.00	3.27	3.17	3.11	12	12	12	41.92	37.78
Multi-stressor Refugia	No	2.25	**4.38**	3.43	3.00	2.89	2.56	8	8	7	40.36	33.27
Wetland Diversity	No	2.00	**4.33**	2.78	3.44	3.78	3.11	9	9	9	36.83	40.50
Potential Climate Refugia	No	2.61	**4.28**	2.83	2.88	2.89	2.76	18	18	18	39.42	33.71

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Gold-Spotted Oak Borer Presence/Spread	No	2.40	**4.20**	3.10	3.30	3.90	3.30	10	10	10	39.11	41.14

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

These metrics appeared in the survey under "Multiple Topics." Though ***Beetle Sensitivity*** has a high *Ecological Integrity* rating, it is a novel metric with no immediate plans for production (though it could be considered for future work). ***Multi-stressor Refugia*** scores more highly for *Ecological Integrity* than ***Potential Climate Refugia***. Survey respondents raised the question of why to focus specifically on ***Gold-Spotted Oak Borer Presence/Spread*** as opposed to other invasive pests; perhaps an aggregate metric could combine multiple pest distributions to reflect areas in danger of biodiversity loss, particularly in the face of climate change. ***Wetland Diversity*** is a useful layer for planning but may not be sensitive to management actions. None of these metrics have particularly good *Understandability, Feasibility,* or *Sensitivity.*

Biodiversity

Table B7: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Wildlife Species Richness	No	1.75	**4.25**	2.79	3.22	3.83	3.13	24	24	24	35.44	39.80
Indicator Species (Habitat, Population or Distribution)	Yes	2.04	**4.12**	2.52	3.29	3.58	3.67	25	25	25	35.19	41.68
Invasive Species	Yes	3.11	**4.00**	2.70	3.54	3.88	3.35	27	27	27	39.94	42.28
Habitat Connectivity	No	2.36	**4.18**	2.77	3.52	3.48	3.48	22	22	22	37.73	41.45

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Wildlife Species Richness, despite some weaknesses (e.g. not including abundance of species), was highest-rated for *Ecological Integrity* in the "Biodiversity" topic and could work well in combination with other metrics. The proposed ***Indicator Species*** and ***Invasive Species*** metrics were favorably received, but could take some work to implement, and therefore were not recommended for immediate use as a core metric. ***Habitat Connectivity*** is a vegetation/landscape metric which should support biodiversity, and was rated reasonably well. The metrics in this topic area did not tend to perform well on *Wildfire Risk* or *Wellbeing* goals, possibly reflecting the limitations of these metrics to measure biodiversity in a way that is relevant for social and cultural wellbeing. In the "Community Wellbeing" topic, ***Culturally Significant Species*** rated highly, but this is a novel metric that does not yet exist and could be an area for further work. We do note that some individual-species metrics may measure the abundance or habitat availability of culturally significant species, but as a statewide, core metric, any 'single species' metric was not rated highly. See also the "Vegetation, Climate, and Biodiversity Interaction" topic for more "Biodiversity"-related metrics. None of these metrics have particularly good *Understandability, Feasibility,* or *Sensitivity.*

Carbon

Table B8: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			**Attribute Scores[2]**			**Number of ratings[3]**			**Combined scores[4]**	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Large Tree Carbon	No	3.29	**4.14**	3.19	3.80	**4.05**	3.75	21	21	21	43.01	45.70
Dead Carbon	No	**4.05**	3.42	2.32	3.42	3.89	3.79	19	19	19	40.18	43.79

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Large Tree Carbon scored the best of the carbon-related metrics for *Ecological Integrity*, though ***Dead Carbon*** scored higher on *Wildfire Risk*. None of these metrics scored particularly highly relative to some other topic areas, possibly reflecting carbon playing a role as a proxy for overall ecological health and wildfire risk. Though ***Large Tree Carbon*** is a forest-focused metric, it was also rated as being *Understandable*. Survey respondents did raise the point that some dead carbon is beneficial, but too much is not, so the metric will not be linear; in addition, tree-focused metrics will not be applicable statewide. Neither of these metrics were rated particularly well on *Feasibility* or *Sensitivity.*

Economics

Table B9: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Economic Impact of Forest Investments	Yes	2.75	2.25	**4.30**	3.35	3.10	3.35	20	20	20	36.51	38.94
Workforce-tracking	Yes	2.88	2.00	**4.44**	3.63	3.56	3.13	16	16	16	36.47	40.61

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Economic Impact of Forest Investments and ***Workforce-tracking*** are both novel metrics proposed by survey respondents. Both scored well on *Wellbeing*, but not the other goals or *Feasibility*, *Understandability*, or *Sensitivity*. Economic variables are also an important area where the RRKs are lacking and extra development effort would be well placed. Some of the metrics included in the "Environmental Justice" section of the RRKs could also apply to "Economics" (e.g. ***Poverty***, ***Housing Burden***, ***Unemployment***, ***Proportion of Low-Income Populations***) but none of those included in the RRKs are better than specific measures (still to be developed) that track workforce development in vulnerable and disadvantaged communities. Neither of these metrics have particularly good *Understandability, Feasibility,* or *Sensitivity.*

Environmental Justice

Table B10: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
CalEnviroScreen score	Yes	1.25	1.00	**4.50**	3.50	3.50	3.00	4	4	4	25.41	39.33
Impact on Vulnerable Populations	Yes	2.80	1.60	**4.40**	3.00	3.20	3.40	5	5	5	34.31	38.03
Proportion of Low-Income Populations	No	2.33	1.17	**4.67**	**4.50**	**4.17**	3.50	6	6	6	31.38	47.89
Poverty	No	2.33	1.17	**4.83**	**4.50**	**4.67**	3.67	6	6	6	31.96	50.27
Unemployment	No	2.17	1.17	**4.50**	**4.50**	**4.67**	3.50	6	6	6	30.07	49.54

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Housing Burden	No	2.00	1.00	**4.60**	**4.60**	**4.60**	3.60	5	5	5	28.99	50.17
Distribution of Native American Populations	No	2.43	1.86	**4.14**	**4.14**	**4.29**	3.14	7	7	7	32.90	45.22
Tribal Lands	No	2.43	2.29	**4.71**	3.86	**4.29**	3.43	7	7	7	36.73	45.29

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

These metrics all received high ratings for *Wellbeing*, as well as *Feasibility* and *Understandability* (but not *Sensitivity*). They did not rate highly for *Wildfire Risk* or *Ecological Integrity*, again potentially reflecting the conception of "Environmental Justice" as separate from these other goals, at least in the currently available metrics in the RRKs. Though these metrics rate much more highly on the resilience goals and some of the attributes than metrics in other topic areas, none of them rate particularly well on *Sensitivity*. This reflects the feature that many of these layers are likely more useful for planning, e.g. ensuring that treatments are placed near low-income and/or Tribal communities to ensure benefit and reduce risk (or away from these communities to reduce health impacts, as appropriate). ***Tribal Lands*** and ***Distribution of Native American Populations*** may not be the best indicators of the relative benefits and harms of management actions on Indigenous people, but some measure reflecting this is an important environmental justice metric.

CalEnviroScreen Score may similarly be a less-than-ideal measure of environmental harm, but given that it is currently available, it may serve in the absence of a better metric for immediate use – and may be more nuanced than Census-based metrics measuring e.g. ***Proportions of Low-Income Populations***, ***Poverty***, ***Housing Burden***, or ***Unemployment***. Novel metrics like ***Impact on vulnerable populations*** need to be developed to monitor the outcomes of treatments on these groups. Unfortunately, that metric is not readily available yet, and further work is clearly warranted. There is also overlap between this topic and the "Economics" metrics above, particularly the ***Workforce-tracking*** metric and related efforts which may be more sensitive than overall unemployment. Also see the "Community Wellbeing," "Economics," and "Community Readiness" sections for additional potential "Environmental Justice" related metrics.

Community Readiness

Table B11: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Built Environment Domain: Hardening	Yes	**4.45**	1.91	3.86	3.32	**4.09**	3.64	22	22	22	40.89	43.33
Evacuation Capacity	Yes	**4.21**	1.47	**4.26**	3.74	**4.16**	3.11	19	19	19	39.38	42.94

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity

[3] These columns indicate the number of ratings being averaged for each resilience goal.

[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Both of these are novel metrics, reflecting a lack of good information in the RRKs regarding community readiness and engagement in fire protection. Both metrics were rated as being *Understandable* (though not very *Feasible* or *Sensitive*), and both rated well for *Wildfire Risk*. ***Evacuation Capacity*** also rated well for *Wellbeing*, and therefore could be viewed as an important priority for creation of future metrics. These metrics may also relate to "Environmental Justice," both in the sense that populations with fewer resources may have reduced evacuation capacity and reduced ability to implement home hardening strategies.

Community Wellbeing

Table B12: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Health Outcomes Related to Air Quality	Yes	2.47	1.47	**4.87**	3.20	**4.00**	3.47	15	15	15	33.93	41.79
Insurance Availability/Price	Yes	**4.00**	1.29	**4.57**	3.86	**4.14**	**4.29**	7	7	7	38.74	48.61
Culturally Significant Species	Yes	2.22	3.28	**4.28**	3.33	**4.06**	3.47	18	18	18	38.54	42.54
Firewise Approved Communities or Communities with Community Wildfire Protection Plans (CWPPs)	Yes	**4.16**	1.79	**4.16**	**4.21**	**4.21**	3.72	19	19	19	40.13	47.81
Community Domain: Educating/Preparing	Yes	**4.00**	2.17	3.50	3.17	3.17	3.00	6	6	6	38.75	36.85
Urban Canopy Cover	No	2.82	2.53	**4.24**	**4.18**	**4.44**	3.80	17	17	17	37.79	48.76

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing
[2] F = Feasibility, U = Understandability, S = Sensitivity
[3] These columns indicate the number of ratings being averaged for each resilience goal.
[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

This set of metrics appeared in the "Multiple Topics" section of the survey, but focuses largely on measures of community wellbeing. They are largely novel/proposed metrics, and unsurprisingly rated relatively highly on *Wellbeing*. ***Insurance Availability/Price***, ***Firewise Communities and CWPPs***, and ***Community Domain: Educating/Preparing*** also rated highly for *Wildfire Risk*. Most were ranked well on *Understandability*, and ***Insurance Availability/Price*** was one of the few metrics considered in the survey to have a *Sensitivity* rating above 4 out of 5. ***Health Outcomes Related to Air Quality*** and ***Culturally Significant Species*** both ranked highly but these are novel metrics that are not yet available and could therefore be important areas for further work. ***Community Domain: Educating/Preparing*** was not a well-defined metric but could be related to concrete accounting of the number of Firewise communities and recently revised Community Wildfire Protection Plans (CWPPs), which while it is a novel metric may be possible to create (it has a higher *Feasibility* rating than the other metrics in this category). ***Urban Canopy Cover***, while an important measure of community wellbeing, may not reflect changes in fire resilience based on management actions and may be a more appropriate operational metric for planning where to place treatments.

Air Quality/Smoke

Table B13: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Potential Smoke Emissions - High Severity	No	3.25	2.75	**4.25**	3.14	3.38	3.50	8	8	8	40.63	39.64
Potential Smoke Emissions- Moderate Severity	No	3.00	2.43	**4.14**	3.17	3.43	3.57	7	7	7	37.80	40.23
Potential Total Smoke Production Index	No	2.71	2.43	**4.29**	3.43	3.43	3.29	7	7	7	37.07	40.06
Potential Avoided Smoke Production Index	No	3.00	2.38	**4.00**	3.00	3.13	3.00	8	8	8	37.07	36.02

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing

[2] F = Feasibility, U = Understandability, S = Sensitivity
[3] These columns indicate the number of ratings being averaged for each resilience goal.
[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

Two of these metrics have been removed from the RRKs (***Potential Smoke Emissions - High Severity*** and ***Potential Smoke Emissions- Moderate Severity***), so despite their ratings, we do not consider them further. In their place, indices of ***Potential Total Smoke Production Index*** and ***Potential Avoided Smoke Production Index*** have been included in the Kits. Measures of smoke production would be very important for tracking air quality impacts of treatments, however weather can strongly influence the air quality impacts of a given quantity of emitted smoke. Further work is needed to create measured or modeled quantities to accurately represent the impacts of fire on air quality. And even more important are the ***Health Outcomes Related to Air Quality*** mentioned in the "Community Wellbeing" topic. These metrics are still to be developed. None of the metrics in Table B13 have particularly good *Understandability, Feasibility,* or *Sensitivity.*

Planning, Soils, and Recreation

Table B14: Average ratings greater than or equal to 4 are shown in **BOLD**; those with ratings less than or equal to 3 are shown in gray.

		Goal Scores[1]			Attribute Scores[2]			Number of ratings[3]			Combined scores[4]	
Name of Metric	**New?**	**WR**	**EI**	**WB**	**F**	**U**	**S**	**WR_n**	**EI_n**	**WB_n**	**Goal**	**Attribute**
Soil Health/Erodibility	Yes	2.50	**4.00**	3.13	3.63	3.63	3.50	8	8	8	38.78	42.47
Duration of Effect of Management Action	Yes	**4.31**	**4.25**	3.75	3.20	3.67	3.00	16	16	16	49.86	38.63
Buffering Potential	Yes	**4.00**	3.11	3.00	3.11	2.89	3.22	9	9	9	41.03	36.68
Visitation Rates	Yes	2.15	1.95	**4.05**	3.90	**4.05**	3.10	20	20	20	31.77	43.24

[1] WR = Wildfire Risk, EI = Ecological Integrity, WB = Wellbeing
[2] F = Feasibility, U = Understandability, S = Sensitivity
[3] These columns indicate the number of ratings being averaged for each resilience goal.
[4] The combined goal score and attribute scores use the global weightings of the three goals and three attributes (global average ratings as shown in Figures 5 and 6) to make a combined score for each metric.

These metrics appeared in different sections of the survey, but are grouped here for visual convenience. Survey respondents highlighted the importance of ***Soil Health/Erodibility*** and pointed out some sources for these data. ***Visitation Rates*** as an empirical measure of "Recreation" was rated above 4 out of 5 for *Wellbeing*, but there is no current metric that exists to measure this. It could, however, be a direction for further work. Both ***Buffering Potential*** and ***Duration of Effect of a Management Action*** were important "Planning" metrics but both are

novel and not very specifically defined at this time. More work will be necessary to refine these ideas before they could be recommended as core metrics. None of these metrics have particularly good *Understandability, Feasibility,* or *Sensitivity*, with the exception of ***Visitation Rates***, which has *Understandability* above 4 out of 5.

Appendix C: Metric Definition Cheat Sheet

Regional Resource Kit Metric Abbreviated Definitions

Table C1: RRK Metric Abbreviated Definitions

Metric	**Brief definition**
Potential Total Smoke Production Index	Index of the modeled potential smoke production (particulate matter that is 2.5 microns or less in diameter, or PM2.5) that could be emitted under fire weather conditions that produce high severity fire effects.
Potential Avoided Smoke Production Index	How much less smoke (as defined by PM2.5 emissions) would be produced from a given pixel by burning under moderate fire weather conditions rather than the extreme conditions that lead to high-severity smoke production.
Potential Smoke Emissions - Moderate Severity	Modeled emissions of PM 2.5 during a moderate severity fire
Potential Smoke Emissions - High Severity	Modeled emissions of PM 2.5 during a high severity fire
Heavy Fuels	Identifies amount of coarse dead wood in the fuel bed
Wildlife Species Richness	Number of native species, or particular groups of species, per pixel
Threatened/Endangered Species Richness	Number of Threatened/Endangered species per pixel
Individual Endangered Species' Habitat/Distribution/Population	Any variable monitoring an individual endangered or threatened species' habitat, distribution, or population
Present Day Connectivity	Characterization of regional habitat connectivity potential in California for plant and animal species whose movement is inhibited by developed or agricultural land uses.
Full Climate Connectivity Network	Linkage network designed to allow for local movements among individual preserves, while supporting landscape-scale regional connectivity
Habitat Connectivity	The relative ability of a species to move across the landscape between patches of suitable habitat; limited connectivity opportunity (1) to irreplaceable/essential corridors (5)

Metric	**Brief definition**
Total Carbon	An estimate of the amount of existing carbon and its location on California's landscape
Above Ground Live Tree Carbon	An estimate of the amount of existing carbon in aboveground live trees
Large Tree Carbon	The sum of branch, stemwood, and foliage for trees over 20 inches in diameter. Intended to represent one of the most stable components of the carbon pool, and can be an indicator of the carbon stock's resilience/stability.
Dead Carbon	Carbon from dead and down woody materials, and the canopies of trees <10" in diameter
Live Carbon Turnover/Residency Time	Average lifetime of aboveground live and dead carbon in years. Locations where the lifetime or turnover time is longer have more carbon in more stable pools, such as large trees or large coarse woody debris. Locations where the lifetime or turnover time is shorter have more carbon in labile pools, such as live or dead leaves.
Sawtimber (Potential Available)	The amount of total existing, aboveground, live tree stem biomass measured in dry weight tons per acre
Biomass (Potential Available)	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.
Costs Of Potential Treatments Per Acre	Current estimates of costs of different treatment methods for different vegetation types; inclusive of costs to move material from the forest harvest site to a processing location, felling, processing, skidding and hauling.
Estimate Of Biomass Residues From A Thin From Below Treatment	Estimates of the total biomass residue generated by a 40% Thin From Below treatment
Damage Potential (In WUI)	Relative measure of wildfire's potential to damage a home or other structure
Structure Exposure Score (In WUI)	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
Ember Load Index	Calculation of ember production that incorporates burn probability

Metric	**Brief definition**
Ignition Cause	Broad classification of ignition source
Probability Of Fire Ignition (from Humans Or Lightning)	The predicted human- and lightning-caused ignition probability
Wildfire Hazard Potential	An index that quantifies the relative potential for wildfire that may be difficult to control.
Current FRI Since 1970	The number of years in the fire record divided by the number of fires occurring between 1908 and the current year plus one
Recent Fire Severity	Fire severity classification (low, moderate, high) that burned within 2012- 2021
Mean Percent FRID Since 1970	Measures the departure of current FRI from mean 1970 FRI
Time Since Last Fire	The length of time since an area last burned
FRID Condition Class For Departure	The extent to which contemporary fires are burning at frequencies similar to the frequencies that occurred prior to settlement
Total Dead/Down Fuels	Total coarse woody debris, litter, and duff
Standing Dead And Ladder Fuels	Live “ladder” fuels for trees less than 10” in diameter
Total Fuel Exposed To Fire	The sum of standing dead, ladders, and the dead and down fuels; total amount of biomass available to contribute to a fire’s intensity and spread
Probability Of High Severity Fire	The probability of high severity fire (defined as the headfire flame length in each pixel will exceed 8 foot flame lengths)
Probability Of Moderate Severity Fire	Probability of moderate severity fire (defined as fire with flame lengths between 4 and 8 feet and can be controlled using mechanical control treatments.)
Probability Of Low Severity Fire	Probability of low severity fire (defined as fire with flame lengths of less than 4 feet and can be controlled using manual control treatments.)
Annual Burn Probability	The likelihood of a wildfire of any intensity occurring at a given location (pixel) in a single fire season.

Metric	**Brief definition**
Natural Conifer Regeneration	Modeled probability of conifer regeneration within a 60 sq m circular area five years after fire
Basal Area	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
Density - Trees Per Acre	Trees per acre provides a useful index of forest and habitat condition.
Density - Snags	Snag density for all species and all decay classes with diameters of 20” DBH and greater
Stand Density Index	Relates the current stand density to the size class distribution of the stand
Proportion Of Max Stand Density Index	Measures the upper limit to the occupancy of a tree stand, at which point growth of the stand is only possible after the death of some individuals. SDI is a measure of the number of trees per unit area relative to the size class distribution of the stand.
Quadratic Mean Diameter	Represents the diameter of the tree of the mean basal area. This is generally preferred over the 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.
Large Tree Density	Density of trees with DBH > 30”
Percent Canopy Cover	The percentage of forest floor covered by the vertical projection of the tree crowns
Fine Scale Heterogeneity Index	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, (fewer canopy interruptions), to 2 (more canopy interruptions).
Canopy Veg Height	The distance between the ground and the top of the canopy; a proxy for aboveground biomass and the amount of foliage that may be consumed in a canopy fire.
Canopy Cover	The horizontal cover fraction occupied by tree canopies; more precisely described as canopy density

Metric	**Brief definition**
Urban Canopy Cover	Represents tree canopy cover for the 2010 Census Bureau urban areas for the Northern California RRK region
Tree Cover	Total tree cover as measured by the fractional non-overlapping absolute tree cover, viewed vertically; (0-100%)
Shrub Cover	Total shrub cover as measured by the fractional non-overlapping absolute shrub cover, viewed vertically; (0-100%)
Herbaceous Cover	Total herbaceous cover as measured by the fractional non-overlapping absolute herbaceous cover, viewed vertically; (0-100%)
Seral Stage Distribution	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
Risk of Tree Dieoff During A Drought	The risk of tree dieoff during a significant drought period. Units are dimensionless; low values are minimal risk and high values indicate significant risk.
Cumulative Tree Cover Lost	Cumulative loss of tree cover over a 30-year period (1992-2021). Tree cover loss reflects fires, harvest/management and dieoff.
Cumulative Shrub Cover Lost	The cumulative loss of shrub cover over a 30-year period (1992-2021). Shrub cover loss reflects fires, harvest/management and dieoff
Gold-Spotted Oak Borer Presence/Spread	Information on detected GSOB mortality
Multi-stressor Refugia	Capacity of sites to potentially provide protection for natural communities from multiple threats including climate, fire, altered river channels, and density of recreational activities
Potential Climate Refugia	Represents habitat types and their predicted exposure to climate stress across an array of predicted future possible climate conditions in comparison to baseline climate conditions
Shrub Resiliency	Count of the number of times each site met a threshold of a 15-year fire-return interval from 1950 to 2019. Can be used to identify sites that have experienced frequent fire
Time Since Last Disturbance	Time in years before 2021 since the most recent disturbance of at least 25% canopy cover loss per 30m pixel

Metric	**Brief definition**
Tree Mortality	Dead tree canopy cover fraction change
Housing Burden	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)
Unemployment	Percentage of the population over the age of 16 that is unemployed and eligible for the labor force
Poverty	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; Percent of population living below two times the federal poverty level
Tribal Lands	Lands within California's boundary that are under the control of federally recognized Tribes
Low Income Populations Proportion	This metric identifies group block areas where low-income households are disproportionately present in comparison to the total low-income population of the region
Distribution of Hispanic populations	This metric identifies Census block group areas where Hispanic/Latino are disproportionately present in comparison to the total Hispanic/Latino population of the region (based on US Census Tiger Files for block groups)
Distribution of Native American populations	This metric identifies Census block group areas where Hispanic/Latino communities are disproportionately present in comparison to the total Hispanic/Latino population of the region (based on US Census Tiger Files for block groups)
Actual Evapotranspiration Fraction	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
Annual Mean Runoff	The expected surplus water that would discharge to surface or groundwater flows during a series of years with average precipitation.
Drought Sensitivity	An estimation of the probability that drought will substantially impact post-fire shrub recovery, potentially leading to vegetation type conversion to invasive grasses and forbs

Metric	**Brief definition**
Change in Average Climatic Water Deficit	A projection of the difference in the mean annual climatic water deficit between the baseline period (1950-1980), and a near future period (2030-2059) under the MIROC (Drier) scenario of climate change.
Reduction in Runoff During Extreme Drought	Calculates runoff during an extreme drought and subtracts from annual mean runoff
Vegetative Stress During Extreme Drought	A measure of the unmet water demand during an extreme drought
Meadow Sensitivity Index	The slope of the relationship between April 1st snowpack and September vegetation wetness
Aquatic species richness	The number of native fish and aquatic invertebrates, amphibians, and reptiles
Wetland diversity	The extent, approximate location, and type of wetlands and deepwater habitats
Riparian habitat	10-meter raster riparian areas for 50-year flood heights in 2019

Suggested Metrics From Phase 1

Table C2: Suggested Metrics From Phase 1

Name of Metric	**Description of Metric**	**Data Sources**	**Measurement/Analysis Methods**
Indicator species (habitat, population or distribution)	Similar concept as suggested for T&E species but focus could be on more commonly detected species that are known to serve as an indicator for ecosystem health.	not sure what CDFW would have standardized data on outside of listed species but could be worth exploring	this is definitely difficult to implement but seemed worth thinking about anyways
invasive species	A measure of the presence and distribution of invasive plant and animal species	Potentially CA Invasive Plant Council and CDFW	
Culturally significant species	In addition to species of special concern that have been federally or state-listed, a measure of the health of species that are culturally significant to Tribal communities as well as potentially others	List of species could be created via a survey, data on those species would depend on the species. Some may be tracked by agencies, but some could rely on crowdsourced biodiversity datasets like iNaturalist	Ultimately could aggregate together to an index
carbon sequestration	The potential of unit area, above/below ground carbon	Federal, State, Private, Tribal	Carbon (biomass) sequestration types, above ground biomass, below ground biomass, and the threat to these from climate stressor (drought/fire).
Area covered by NEPA/CEQA analysis that can or could receive fuels/fire treatments	Acres of land having completed NEPA/CEQA	Federal and State, Tribal if applicable	Proportion of "shovel ready" covered acres for fuels, mechanical/timber harvesting, and prescribed fire can cultural burning vs. what was treated by each type of fuels, manual/mechanical-timber, and prescribed fire

Name of Metric	**Description of Metric**	**Data Sources**	**Measurement/Analysis Methods**
Built Environment Domain: Hardening	This metric -- or set of metrics -- would capture the vulnerabilities/sensitivities of homes and shared infrastructure to various types of losses or negative outcomes.	For example, patterns of structure ignition vulnerabilities of different types, road network bottlenecks during evacuations, temporary refuge areas, water supply deficiencies during critical flow needs, power line infrastructure posing key ignition risks, etc	Modeling/mapping current situation and potential future (i.e., after mitigation of various risks related to not being "hardened")
Evacuation capacity	road network, traffic record, housing density and etc		
Firewise approved communities or communities with Community Wildfire Protection Plans	Level of preparedness for human communities should be reflected somewhere, this is key to resilience. I think integrating a layer like Firewise (rather than CWPP) better reflects community awareness and involvement.	Here is the link to CWPPs. Community Wildfire Protection Plan Portal and Data Library - Fire Adapted Communities	
Community Domain: Educating/Preparing	This metric -- or set of metrics -- would capture the vulnerabilities/sensitivities of human communities to various types of losses or negative outcomes.	For example, patterns of level of neighborhood organization, renter vs owner %, degree of Firewise USA engagement, etc.	Modeling/mapping current situation and potential future (i.e., after mitigation of various risks related to being unprepared)
Economic impact of forest investments	Economic impact of forest investments. Could include (1) measure additional economic activity ($), (2) additional jobs, and/or (3) additional employment income.	Several options but IMPLAN is probably the most widely used tool for this task.	Annual metric that could be reported down to the zip code level. Or up to a county/multi-county aggregation. Would require gathering information about $ spent on investments and number of new people hired to carry out investments. Then an economic analyst would prepare an economic

Name of Metric	Description of Metric	Data Sources	Measurement/Analysis Methods
			impact study that would generate the desired economic metrics. For an example, see this economic impact tracking program in SE Alaska. Nearly identical methods and outputs...
multi-benefit valuation of potential management action	aggregate of multiple metrics in ways to identify higher vs lower value areas using user-chosen combinations of other metrics. In this way	other metrics, plus appropriate library of valuation data	Net present value over projected life of management action is a good starting point. Can develop statewide
Workforce- tracking	Workforce availability and/or workforce gaps	California Employment Development Department tracks employment and wages by county and sector through the Quarterly Census on Employment and Wages (QCEW). Data is available here...	The above data source can be used to directly track employment over time. However, it's probably more useful to identify workforce "gaps". That is, regions and sectors where labor demand exceeds labor supply. This will help the task force track critical bottlenecks to expanding pace and scale. I am not aware of an existing metric that currently exists for this but I think it's worth thinking about how to develop it.
valuation data	valuation in dollars and non-dollar metrics, needed to develop value proposition for reducing risk & improving condition. Used with cost of management metric in net present value calculation	compiling empirical data. we have done some of this, and needs more work.	both market data & social value data from literature, grey literature, interviews & surveys
Insurance availability/price	Some measure of how many people in an area rely on state-managed	unknown	unknown

Name of Metric	Description of Metric	Data Sources	Measurement/Analysis Methods
	insurance, or how many people are not able to get insurance/have their policy dropped. Could be a measure of wellbeing as well as resilience.		
CalEviroscreen score	Census tract -level environmental burden score	https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40	See reference
Impact on vulnerable populations	Measure anticipated benefits or challenges that may accrue to vulnerable populations with the goal of growing benefits and eliminating challenges.	Calenviro screen. Results of community engagement events, focus groups, surveys.	Survey and community engagement event done in partnership with local grassroots organization.
Repeated high severity fire	Tracking how many times areas that were previously forested burned severely. This would get at the potential for a persistent type conversion in forests (similar to what you have for shrub resiliency)	RdNBR, 30m pixels	Overlay high severity areas within forested regions. Could be only burns that repeat within a given time frame or jsut total them and give the first and last year of high severity.
Fire regime	Description of frequency at which fires in a given ecosystem typically burn, the season(s) in which they burn, and the typical historical burn severity.	FRID, FRCC, LandFire	
Ratio of high to low/moderate severity wildfire	Calculated from burn history maps? Or modeled probability of different severities?		
Health outcomes related to air quality	Aggregating numbers produced by counties and other health systems on rates of asthma and other respiratory effects	County health departments and similar	Would not be linked directly to wildfire specifically (there are other causes of bad air quality) but could be used in combination with other variables.
Climatic Water Deficit	The annual evaporative demand that exceeds available water. I didn't		

Name of Metric	Description of Metric	Data Sources	Measurement/Analysis Methods
	see this metric, though usually do - do the evapotranspiration metrics cover the same information somehow better?		
Snow "at risk"	Landscapes where a loss of snow is very likely r	Can be extracted from snow products and/or climate data	Empirically derived from historical snow observations and/or climate data
duration of effect of management action	use historical data to project effect of management action on key metrics (ET, carbon, vegetation, projected flame length) over time following management actions or wildfire of various severity	We have developed a library for some of these using CECS data, and more can be done to fold these into metrics	Track time series of landscape response to past disturbance. As a later step, project into future climate
Land management decision authority	Categories that represent who is making land management decisions, ie Forest Service, Nation Park, Federal agency with Tribal cooperating agreement	Land management plans	
Buffering potential	This metric -- or set of metrics -- would capture the vulnerabilities/sensitivities of the landscape and WUI to penetration by wildfire. It/they would reflect the value of treating a site because doing so could offer a buffer of protection to high value habitats or communities, could facilitate suppression efforts, or slow down fire spread	For example, buffering potential of current and future agricultural lands, shaded fuel breaks of native tree spp, irrigated public space, wetlands and riparian areas of high foliar moisture, etc.	Running a bunch of FarSITE models with different ignition locations and fire conditions Modeling/mapping current situation and potential future (i.e., after mitigation of various risks related to being unbuffered)
Visitation Rates	Number of people visiting County, State, National, and Private parks	National Park Service, California State Parks, nonprofits and land trusts	Simple monitoring over time for a given park or location to reflect public

Name of Metric	Description of Metric	Data Sources	Measurement/Analysis Methods
		that might collect visitation or usage numbers	engagement with the space
Citizen Science engagement	Using number of submissions to crowdsourced biodiversity platforms and similar sources, calculating a measure of people engaging with the outdoors	iNaturalist, eBird, and similar datasets	Measuring number of users in different places, rather than their biodiversity measurements, similar to NCEAS' assessment of coastal engagement
Soil Health/Erodibility	Soil erodibility represents soil detachability, runoff potential of the soil, and the transportability of the sediment eroded from the soil.	https://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/constpermits/guidance/k_factor_map.pdf	Empirically derived from soil properties
erosion potential	magnitude of potential erosion following wildfire of various severity, and reduced potential with management action to reduce projected severity	see CECS metric on this, plus additional work by Safeeq Khan	based on canopy cover, erosion index & other variables
beetle sensitivity	Susceptibility to drought/bark beetle infestation	Historical data from recent prolonged drought and mortality event	Field data and statistical analysis; although others, like Adrian Das, would be better qualified to determine this.
Shrub post-fire regeneration strategies	Multinomial model to map distribution of obligate seeding, obligate resprouting and facultative seeding shrubs.	Underwood, E.C., Q.M. Sorenson, C.C. Schrader-Patton, N.A. Molinari and H.D. Safford. Resprouting, seeding, and facultative seeding shrub species in California's Mediterranean-type climate region. Frontiers in Ecology and Evolution 11:1158265. doi: 10.3389/fevo.2023.1158265	

Name of Metric	Description of Metric	Data Sources	Measurement/Analysis Methods
Areas of low potential shrub regeneration	Identification of shrubland pixels with low regeneration potential postfire given fire history.	Underwood, E.C., and A.D. Hollander. 2023. Areas of low natural regeneration potential post-fire in shrublands of southern California (selected years between 2008 and 2020). Dryad, Dataset, https://doi.org/10.25338/B8CH2T	
Shrub biomass data for southern California	Includes estimates of all pools: aboveground live, dead, litter, and belowground.	Schrader-Patton, C.C., E.C. Underwood, and Q.M. Sorenson. 2023. Annual biomass spatial data for southern California (2001–2021): Above- and belowground, standing dead, and litter. Ecology e4031.	Schrader-Patton, C.C. and E.C. Underwood. 2021. New biomass estimates for chaparral-dominated southern California landscapes. Remote Sensing, 13, 1581. https://doi.org/10.3390/rs13081581
Mature forest habitat	We spend a lot of time talking about the individual species of interest and their habitat suitability related to the presence of mature habitat but I think it could be helpful to monitor the habitat directly in this way because so many sensitive forest species depend on mature habitat features (e.g., snag trees, old trees, down woody debris) and this is something that can be directly managed for	not sure	