Landscape Assessment (LA)

Sampling and Analysis Methods

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GROUND MEASURE OF SEVERITY: THE COMPOSITE BURN INDEX

These methods are used to derive index values that summarize general fire effects within an area, that is, the average burn condition on a plot. They are designed for moderate-resolution remote sensing applications, assuming a landscape perspective of entire burned regions. As such, plots are fairly big and widely spaced (>90 meters apart). Field data are relatively quick to collect (about 30 minutes per plot), relying mostly on ocular estimation and judgment. This allows a representative number of plots to be sampled effectively over large areas. The primary task is to encompass the range of variation found within burns, covering as many fire effects and biophysical settings as possible.

A characteristic of sampling is that within a plot, average conditions of many factors are considered across multiple strata to derive the severity value. This led to naming the approach the Composite Burn Index, or CBI. It logically parallels the way Landsat satellite sensors average all features within a pixel to record the multi-spectral brightness values used to model burn severity.

CBI information is not solely limited to remote sensing, however. Field data can stand alone for general burn assessment, as a way to summarize conditions exceeding a few hectares. Methods work at stand or community levels to estimate the combined severity of individual factors. Data may be useful for reconnaissance, rapid assessment after burning, planning rehabilitation, documenting results of prescribed burns, or any activity where burn information needs to be gathered relatively quickly over large areas. Other methods within FIREMON address smaller-scale sampling for detailed fire effects on individual components of a community. Those can complement the CBI when more site-specific information is needed.

The landscape sampling design is hierarchical and multi-layered. Each strata of a vegetative community is evaluated independently by several criteria and given a rating. Scores are decimal values between 0.0 and 3.0, spanning the possible range of severity between unburned and highest burn effect. Scores may be combined (averaged) to yield aggregate CBI ratings for the understory, the overstory, and the total plot. Table LA-1 shows the three composite levels (lettered) and five strata (numbered) currently used.

The total plot CBI comprises all five strata, when all strata are present. When plots do not contain all strata, those missing strata are simply not counted. Ratings may be reported separately by strata, or in their composite forms, depending on objectives.

What do CBI values mean?

The CBI provides an index to represent the magnitude of fire effects combined across all strata per sample area of a community. Ratings incorporate such factors as condition and color of the soil, amount of vegetation or fuel consumed, resprouting from burned plants, establishment of new colonizing species, and blackening or scorching of trees. As a continuous numeric value, the CBI is useful for correlation with environmental variables, such as plant productivity or fuel loading, and is well suited to communicate the salient attributes of burns among managers and researchers. For example, you might calculate a CBI score of 1.4 for one area and over time compare vegetative recovery there to another area with a CBI of 2.3. In addition, the CBI may be stratified into ordinal levels, as a basis for tabulating area statistics or aggregating effects. You then may report impacts in terms of low, medium and high severity merged over multiple burns, for example.

The question CBI attempts to answer is how ecologically significant are consequences of a given fire; or how much has fire altered the biophysical conditions of a site? It provides a numeric scale, from 0.0 to 3.0, for gauging those changes. CBI is not uniquely weighted for different community types. Rather, by definition of severity, it attempts to gauge the magnitude of change from pre-fire conditions. Thus it should provide comparable values regardless of community type, location, or time. It is inherently relative to pre-fire conditions and not an absolute value, like weight of fuel per unit area. A distinction is made that a given fire intensity can produce variable degrees of burn severity, depending on site or vegetation characteristics. For instance, low to moderate fire intensity will likely generate more severe consequences in stands of thin-barked tree species, like spruce, than on thick barked species like ponderosa pine. The CBI should register such differences appropriately, yielding higher values in the spruce stand than in the pine stand, even though the fire intensities for both were about the same. Thus, CBI does tend to reflect a community's sensitivity to fire when fire intensity is constant.

A second example is worth considering. In herbaceous communities, fire intensity is normally lower than in forested areas, due to less fuel loading and stratification. Consequently, burn severity is usually less and more ephemeral than in forest. In most cases, fire actually enhances productivity of herbs through the first or second growing seasons after fire. This is partly a response to nutrient cycling and reduction of aboveground competition; while belowground heating is low and minimally damages roots or rhizomes. In such situations, CBI is predominantly based on the lower two strata of the understory, yielding very low but positive overall severity scores. It rarely attains the levels observed in forest burns, and reflects the true nature of low fire impacts to herb communities. It is not a relative measure considering herb communities alone. Enhanced productivity, above 100 percent of what it was before fire, is presently being evaluated for CBI. Currently, it is captured by variables in the herb and shrub strata, but is not yet averaged into CBI ratings.

Keep in mind, CBI is geared to correlation and validation of 30-meter Landsat data. It helps answer the question of satellite mapping performance for large burned areas. Hence, emphasis is on a large plot size, multi-strata average conditions, covering the range of effects with sufficient replicates, and sampling broad areas efficiently.

Sampling for the Composite Burn Index

Time since fire is relevant to how factors appear when a plot is sampled. Therefore, it is essential to plan field work for specific objectives, and to enter the "fire date" on the field form, so you can track the timing of field data. If you are interested in short-term severity (first-order fire effects), the optimum time for fieldwork is during the first post-fire growing season. This would correspond with the timing for *extended assessment*, which is the primary reference point for change from pre-fire conditions, as it reveals survivorship potential and delayed mortality. That timing naturally varies by ecosystem, however. It can be as long as 9 to 11 months in relatively cold climates, or as short as a few weeks in sub-tropical regions.

If plots are visited soon after fire, as in *initial assessment*, many effects will be evident, but ability to estimate survivorship and delayed mortality will be diminished. New seed germination and resprouting likely will be missed, as will effects on trees stressed but not immediately killed by fire. Soil properties may also be obscured by ash that has not had time to wash off. A solution for initial assessment may be to simply omit some factors from consideration, but that could weaken the validity of CBI. At the least, detective work may need to be increased to make reasonable ratings of such questionable factors.

If plots are visited beyond the first growth period after fire, short-term effects become increasingly obscure. Data then reflects elements of recovery that may largely depend on post-fire climate, soil, or other factors, and only partly on the first-order fire effects establishing a site's new ecological starting point. Intervening litter fall and prolonged growth, for example, may lessen the apparent magnitude of short-term severity. Under these circumstances, assessment may require calibration of observed responses back to what they were like one growing season after fire. Counting back the annual nodes of growth on shrubs, for example, can help determine the resprout status in previous years.

On the other hand, revisiting plots several years after fire does provide useful information about long-term severity and recovery rates. Imagery and plots can be compared if they have similar sampling intervals since fire. A time-series of CBI data can be used for multiple change detection experiments in remote sensing, and importantly, to help verify predictions made about severity from initial and extended assessments. The timeframe may be compressed in semi-tropical regions to perhaps as short as one year, and be practical for monitoring prescribed fire effects. For such objectives, a plot can be read straight up, as it appears at time of sampling. Some factors may be relatively static, like percent of black tree canopy, while others may change markedly over time, like percent of trees felled or shrub and sapling regrowth. Record "fire date" on the CBI form, and do not loose sight of time being an important variable in analysis.

We recognize that ground data may never be available on many burns, given the constraints of time, funding and logistics. Therefore, we expect some remote sensing results to be calibrated or validated with field data collected from different areas. We presently see no problem with this, so long as the burns are similar and remote sensing data is acquired with similar timing. Once a number of burns have been sampled in a region, statistical confidence in the remote sensing results should increase to a point where the need for new ground data should diminish. It can continue to be collected, but only to spot check results. That is, in fact, one goal of the whole process, so field time and expense can be minimized, without sacrificing reliability and availability of burn information. In all cases, the level of validation should be documented in the FIREMON Metadata table.

Sample Design and Site Selection

For remote sensing applications, we prefer a stratified sampling design that attempts to represent the full range of severity with equal sampling effort across it. The main objective is to analyze statistical association between burn severity observed on the ground and the variation derived from satellite data. There is no need for CBI samples to estimate the spatial composition of the burn itself, since the remote sensing product will eventually provide a complete tally of the entire "population" of burned pixels. Thus, the sample of CBI plots only calibrates and/or validates remote sensing, with less necessity for strict spatial randomization.

In most cases, depending on burn size and complexity, 50 to 100 plots per burn are adequate. This should yield suitable sample size to determine how well remotely sensed severity correlates with field measures. If several burns from the same year are being assessed in one area, plots can be distributed over multiple burns. The number of plots is somewhat independent of burn size, if total burn area is larger than about 1000 ha (2500 acres). Large burns tend to exhibit an adequate range of severity in proportional area sufficient for sampling. Smaller burns are typically not as diverse and may be covered by as few as 20 to 40 plots. To spatially stratify the sample, limit plot selection to suitable locations defined by accessibility and data-content factors. Ownership, topography, and distance to roads and trails are key elements when overlaid in a GIS to mask out unsuitable areas.

If the delta NBR (**dNBR**) is available (see the **Remote Sensing Measure of Severity: The Normalized Burn Ratio** section), additional stratification based on the severity level and the amount of localized heterogeneity may be warranted. You would attempt to draw locations from small areas that show minimal spatial variation in **dNBR**. Such stratification can be based on the 3 x 3 pixel matrix of **dNBR** for each pixel being within a range of about 0.15 **dNBR** of its neighbors (maximum – minimum ≤ 0.15), or 150 if **dNBR** is scaled by 10^3. Some experimentation may be necessary to arrive at minimum variation that offers sufficient areas for sampling, with the cutoff being as low as practical. One may find enough sample pixels, for example, with the cutoff for local variation being set as low as 0.10 **dNBR** (100 if **dNBR** is scaled by 10^3). Pixels satisfying that requirement would tend to be located in areas of fairly homogeneous severity, and would generally represent surrounding pixels. Sampling those pixels would lessen problems associated with geo-rectification accuracy of satellite imagery, and locational error in the field. It would help ensure that plots were sampled from the intended areas. It would also help associate a given CBI value with the appropriate **dNBR** value in analysis. Moreover, it would reduce the chance of vastly dissimilar or non-representative nearby pixels from affecting the site through autocorrelation of reflectance from adjacent pixel values. Likewise, such pixels would have less chance of corrupting a local **dNBR** average, if a pixel-neighborhood approach was used to compare **dNBR** to the CBI.

After suitable sample areas are delineated, attempt to randomly draw roughly equal numbers of target locations from each of the general ranges of severity: unburned, low, moderate-low, moderate-high, and high. Plan for about 10 to 20 plots in each of those levels. Unburned sites will be visited only to verify that none of the plot burned, so effort per plot should be minimal in those cases. A histogram of pixel **dNBR** frequencies within the burn can be used to check whether or not selected locations adequately sample the range of variability within the burn. At this stage, the severity levels are just based on best available knowledge. They are likely to change slightly during the course of the survey, so anticipate some adjustment in sample target areas as work progresses.

The way locations are selected within the stratified sampling area can be either random or non-random. Stratified random locations raise fewer doubts from independent reviewers, and may be more appropriate for some statistical analysis. There is often a trade-off in effort and doable sample size with spatial randomization, however. Objective but non-random selection gains substantial field efficiency by the ability to group plots near one another, or along routes traversable in a day. More plots can be done that way, and sampling can often achieve adequate representation with fewer plots across the total range of severity, than can random locations. Furthermore, judgment in the field can be exercised to pick up additional plots while walking through large areas that seem to represent certain burn conditions, but were overlooked in pre-selection.

Spatially random design without stratification is not advised in large or remote burns, since access to many sites will be prohibitively time consuming, and many will end up being excluded because they fall in highly heterogeneous or otherwise unsuitable areas. Moreover, randomization leads to sampling the levels of severity in proportion to the area covered within each burn, not in equal numbers per severity level, and each burn is unique in regards to its spatial composition of effects. Total randomization generally requires more plots than stratified random or non-random sampling in order to collect enough plots from severity levels of limited distribution within a burn. Thus, random sampling would only be called for if one hopes to represent the entire population of burned pixels from the sample, or attempts to estimate the spatial composition of the burn. By contrast, the objective here for CBI plots is to represent all levels of severity more or less equally for the limited purpose of ascertaining the nature of the relationship between severity on the ground and the magnitude of change detected by **dNBR**.

Keep in mind; the greatest expense of time is usually getting to sites in the field. It is best to err on the side of collecting more sample plots, than to get fewer plots while trying to reach remote and hard-to-access areas of the burn.

Plot layout

In the field, navigate to pre-selected target areas by GPS and locate the plot center. In most cases that will be at the pre-selected coordinates. However, at times that location may not be suitable for one reason or another. Try to select locations that 1) represent the range of variability found at the site; and 2) fall within relatively large homogeneous areas, preferably 60 x 60 meters (200 x 200 ft) of basically the same fire effects. This allows a plot to be placed somewhat centrally in the larger area, to be representative yet not too close to adjacent areas exhibiting different fire effects. ("Too close" depends on remote sensing resolution. Here, we are considering 30-meter Landsat data, so try to stay at least 45 meters from edges.) Plots should be spaced at least 90 meters apart. If more than one plot can fit within the target area, attempt to sample that as well, depending on time constraints. Though an area may look patchy or mottled with burn, it may still represent a level of severity that is characteristic of the burn, especially where impacts are light to moderate. In those cases, look for areas with the same degree of small-scale patchiness throughout. Remember, the plot and the Landsat data are integrating surface characteristics over about 900 square meters (0.25 ac), so try to envision the land from that perspective when in the field.

In some validation studies, it may be necessary to have a subset of pre-selected plot locations, which are *never* deviated from in the field. In those cases, proceed to locate the plot center as precisely as possible at the specified coordinates. Attempt to read the plot even if it seems unacceptable due of edge effects, for example, and note such problems on the CBI form. A decision to keep or reject the plot can be made later. If a more representative site exists nearby, it may be worthwhile to add another plot there, since the crew has already made the effort to reach the area. That plot, then, could be used for calibration, even if it may not serve in validation.

At plot center, set the GPS to coordinate averaging mode, and let it acquire data over about 10 minutes or so. Record the GPS location in UTM coordinates to the nearest meter, noting the zone number, geodetic datum, and the amount of error. Mark the plot center so it can be identified temporarily while taking plot data. From plot center, stretch two tapes out to locate the plot perimeter at a 15-meter (49 ft) radius or 30-meter (98 ft) diameter . In open plant communities, it may be sufficient to just lay two tapes on the ground crossing at 90 degrees at plot center. Mark the plot perimeter at the end of each tape with flagging so that the boundary is discernable. At times, if understory effects are relatively complex or the plot is too difficult to walk through, one can use a nested 20-meter (66 ft) diameter plot (10-meter, 33 ft radius) for the understory, while keeping the 30-meter (98 ft) diameter plot for the overstory. If 20-meter understory and 30-meter overstory plots are used, the two different plot sizes need to be marked. If you do not plan to return to the plot within a short time, remove all flagging before leaving. Recorded GPS coordinates will serve to relocate the plot if revisited in the future.

Plot Sampling, Using the Field Form

The Field Form (provided as a separate attachment) cues all information needed to calculate CBI values for the plot. Each stratum present on the plot is evaluated independently by a number of factors. The basic data are severity scores in decimal increments (0.0 to 3.0) that express the magnitude of fire's impact on the individual rating factors, such as, litter and duff consumption. The criteria used to score each factor are given in more detail in the **Field Documentation** section, but they generally correspond to break points along an escalating scale of effects. For example, if the proportion of tall shrub resprouting is around 90 percent, you would assign that factor a score of 1.0; for 30 percent regrowth the score would be 2.0.

It is beneficial to work in teams of two or three. The crew can either evaluate the plot independently or together, but at some point before recording final ratings, try to reach consensus on each factor. It is beneficial to compare impressions and discuss why each score was given. This process aids consistency, adds confidence in the ratings, and generally leads to better understanding of fire ecology on the site. The team may consider understory criteria first and then the overstory. With a day or two of experience, a plot can be completed in about 30 minutes (not including travel time to the plot).

Take a while to become familiar with the strata on the plot and the factors used to rate each stratum on the **LA Field Form**. Refer to the **LA Cheat Sheet**, and especially to the definitions of strata and rating factors provided in the **Field Documentation** section. Take time to walk over the whole plot, looking for clues that point to particular levels of burning. For example, dig through litter and duff, and examine stems focusing on amount consumed, depth of charring, and survivorship. Consider the condition of tufts of grasses. Charred bark or buds may conceal living tissue with potential for regeneration, even though elapsed time may not be sufficient for that to occur. Also, remnant woody material on burn plots usually indicates previous vegetation structure; look for the snags or stubs of former trees and shrubs. Finally, it helps to compare nearby unburned areas to gauge what might have been present on the plot before burning; base similarity for comparison on topographic factors, soil type, and the density and size (age) of trees. Keep this in mind when traversing unburned terrain on the way to burn plots.

Once comfortable with general understanding of the plot, enter the plot descriptive information at the top of the CBI form. Then determine and enter the amount of burned area within the 30-meter plot (98 ft) that is, the percent of plot area showing *any* impact from fire. Make that determination also for the nested 20-meter (66 ft) plot if it is used. Area estimators at the bottom of the form can be used throughout the exercise to help resolve percent cover in a plot. Also for each stratum, there are a few variables to describe pre-fire conditions. They are entered early on to serve as benchmarks for estimating the amount of change called for later in some severity factors. These preliminary entries are important, so please make every effort to record them.

Proceed down the Field Form stratum by stratum, scoring each factor between 0.0 (no burn effect) and 3.0 (highest burn effect). Factors are designed to take decimal scores, so you may score a 2.8, for example, if you feel the condition is not quite a 3.0 but definitely more than 2.5. It is important to decide where a rating falls in reference to average conditions over the whole plot. In other words, if there is patchy distribution of both moderate and low burn effects, average those aerially together, and mentally determine an overall score. It likely will be somewhere in the middle, depending on proportions of each level plot-wide. Scores generally reflect the degree of change from the pre-burn state, e.g. the proportion of fuel consumed. If herbaceous cover was sparse before fire, for example, you would not necessarily give a high score to sparse herb resprouting observed after fire. It would depend on how the herbs are doing, relative to how dominant they were before fire.

If some factors (or strata) do not apply to the plot, then do not count them. On the field form, however, you should note why the factor was not assessed so people do not think you simply forgot to record it. The entry may either be "not applicable" (N/A) when the rating factor is insignificant or not present, or "uncertain" (UC) when the factor may be present, but one cannot make a reasonable determination about it. Such fields are ignored during analysis. For example, the plot may have big trees but no intermediate trees. Then the intermediate trees simply would be N/A and not be rated, so the overstory CBI would be based on just the big trees. Do not score non-applicable factors as zero. A zero score means that a factor was present, and it was ratable at a level determined to be unaffected by fire. Zero ratings *do* get averaged into CBI scores.

When all factor scores are entered, calculate an average rating for each stratum, and the CBI for understory, overstory, and total plot. That is done by adding up scores within each hierarchical level, and dividing by the number of *rated* factors. To get overstory CBI, for example, total intermediate tree and big tree scores, and then divide by the number of factors rated for both intermediate plus big trees. For total plot, add up all factor scores and divide by total number of scores rated in all strata. Note, when entering data using the FIREMON software, CBI values are calculated automatically by the database, which helps to double check scores entered on the field form.

Before leaving a plot, review the CBI ratings. See that they make sense and adequately correspond to interpretations of the plot. If not, examine strata ratings; consider and discuss which one(s) may be questionable, and why. You will often find that severe impacts in one stratum are mitigated by lesser impacts in other strata. This is an intended result when aggregate CBI ratings are calculated. Differences of a point or less between observers on individual factors usually make little difference in overall CBI ratings. Thus, it generally is not worth adjusting the disparity in single factor scores unless they are quite different after complete CBI ratings have been calculated. Remember, you are interested in cumulative impacts of fire over the vertical structure in a community, and over the whole area of a plot. The first impression of a plot may be biased toward obvious conditions in one strata, but when all strata are considered independently and averaged, one often agrees that the "real" composite effect is different from that first impression.

Finally, enter community notes or comments about burn patterns within the plot. These are important attributes to know in subsequent analysis. Things to consider here include: height and density of the various strata; dominant species present per strata; general fuel characteristics; general microclimate and moisture; topography; evidence of insects or disease; and any descriptors about the burn mosaic. Other comments may refer to the suitability of the plot, for example, when the plot straddles an edge or has signs of disturbance other than fire.

There are two reasons to also note observations that may not directly relate to the CBI. First, fieldwork is expensive and time consuming, so it is most efficient to gather all potentially useful information the first time and avoid having to revisit a site by you or others. Second, fire affects many things that may be of interest to others in a variety of disciplines, and it is always beneficial to demonstrate a service to the areas one visits. Thus, recording any information that may potentially be useful is encouraged. That may include observations of rare plants or weeds, cultural resources exposed or affected by fire, interesting wildlife sightings (including carcasses), as well as erosion or water quality evidence. It is always good to communicate with local resource and cultural specialists before fieldwork to be better informed on what to look for, and to find out what may be of interest.

Field interpretations for the CBI are forced to be a little fuzzy and based on best judgment. They must assess change to a site, usually without quantifiable data on what was there before fire. In addition, some estimated effects are time dependent and may not become manifest for a while after fire. These are just inherent circumstances of burn evaluation. It is much like forensic ecology. Do the best you can, and with experience, you will get increasingly comfortable untangling the sometimes-puzzling evidence of burn severity.

Plot Photos

It is a good idea to take photos after completing the rating exercise, when you are most familiar with plot burn conditions. There are many approaches to this, but some recommended procedures include the following. Use a high-resolution digital camera, or a 35 mm camera with color slide film, ASA of about 125. Take at least two photos approximately 180 degrees opposite one another, showing the plot center and about half of the plot in each. Avoid taking photos directly toward the sun, especially under darkened forest canopy. Include a signboard for scale, and to identify the date and plot number in the picture. As time or objectives allow, take other photos targeting features of interest; e.g. typical charring patterns on substrates or trees, and re-growth on perennial herbs and shrubs. Try to capture tree canopy effects as well as ground effects. It is also useful for training or presentations to take photos specifically to represent different severity characteristics or fire scenarios, and problems encountered in the field, whether or not they fall on a plot.