Wildfire threat to key resources on the Beaverhead-Deerlodge National Forest

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for the:

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Introduction

TEAMS conducted a mid-scale multi-resource assessment of wildfire threat and benefit for the Beaverhead-Deerlodge National Forest (BDNF). The assessment was patterned after the method described in the “first approximation” of nationwide wildfire hazard and threat (Calkin et al. 2010). Although nominally a “threat” assessment, the procedure employed in this analysis quantifies benefit to key resources as well as threat.

The BDNF wildfire threat assessment process consists of three components: wildfire hazard, exposure of key resources to that hazard, and the susceptibility of those resources to wildfire. Wildfire hazard was quantified using the FSIM large fire simulator, which produces spatially resolved estimates of burn probability by fire intensity class across the Forest. Resource exposure to wildfire was determined by obtaining geospatial data indicating the locations on the Forest where each resource occurs. Resource susceptibility was determined by expert-opinion development of a response function for each resource.

The analysis area for this assessment includes the 8 million acres within any of the 12 BDNF landscapes (figure 1), regardless of ownership. The wildfire occurrence and growth modeling system used in this analysis can simulate the start and spread of wildfires into the BDNF analysis area from adjoining lands. A 5-10 mile wide buffer around the Forest is needed to ensure that such fires are properly accounted. The wildfire modeling system also requires its geospatial data to be a rectangle. Therefore, the fire modeling area is a rectangle around the buffered forest boundary, encompassing more than 15 million acres. This fire modeling area includes private land, land administered by other National Forests, and land managed by various state and federal agencies. Although fire modeling was performed on this larger area, wildfire threat was assessed only on land within the 12 BDNF landscapes, regardless of ownership. For example, wildfire threat to key resources on the Helena National Forest was not addressed, but wildfire threat to residential structures in private land within the analysis area was.

The objective of this wildfire threat assessment was to identify potential vegetation management opportunities to meet forest plan objectives (protect and enhance key resources). This was accomplished by quantifying threat and benefit in the analysis area and summarizing those results to the BDNF landscapes. This assessment is intended to provide a mid-level snapshot of wildfire threat that can be used to identify management opportunities. It is not intended to support the identification of specific treatment units or to compare the effects of alternative treatments on wildfire threat and benefit. However, the wildfire hazard and threat modeling process developed for this assessment can be applied in the future to address those project-level questions.

Figure 1. Map of analysis area. The twelve landscapes are shown in different colors.

Wildfire Threat Assessment Process

As mentioned in the Introduction, the BDNF wildfire threat assessment process consisted of three components: characterizing wildfire hazard, mapping key resources exposed to that hazard, and quantifying the susceptibility of those resources to wildfire. These three components are described in the following sections, followed by a description of the calculation of wildfire threat and benefit.

Wildfire Hazard

We used the FSIM large fire simulator to estimate annual burn probability (BP) and mean fire intensity (MFI) across the BDNF. FSIM operates on three primary data sources: landscape, fire danger (fuel moisture content trends) and fire occurrence.

Landscape data

The ongoing outbreak of bark beetles on the BDNF is the primary reason for conducting the wildfire threat assessment at this time. The primary focus of our assessment is a snapshot of wildfire hazard and threat as of 2009 – the effective date of a study of the effects of the outbreak on forest canopy cover loss (Ahl et al. 2010). We also simulated hazard and threat at a hypothetical time at the end of the outbreak, assuming that the beetles continue moving across the forest and eventually affect all beetle-susceptible stands. The following sections describe the method used to develop these two landscape datasets.

2009 Landscape data

FSIM requires a “FARSITE” landscape file (LCP) in order to simulate fire spread. An LCP consists of geospatial data on terrain, fuel and vegetation. Terrain factors include slope, aspect and elevation. Fuel factors include surface fire behavior fuel model, forest canopy base height and forest canopy bulk density. Vegetation factors include forest canopy cover and forest cover height. LANDFIRE is a common source for such data; however issues exist with applying LANDFIRE’s off-the-shelf landscape data for mid-scale assessments in general and the BDNF specifically. First, the analysis area includes portions of four LANDFIRE mapping zones, resulting in data discontinuities (seamlines) at mapping zone boundaries. Second, rules for mapping fuel characteristics are generalized to the LANDFIRE mapping zones which span tens of millions of acres each, therefore resulting in imprecision at this finer scale. Third, LANDFIRE’s published forest canopy cover data are known to overestimate this factor. For these reasons, we held a “local fuel calibration workshop” with BDNF fire and fuel staff to produce seamless, locally calibrated surface and canopy fuel data, based on LANDFIRE’s core mapping of existing vegetation type (EVT), existing vegetation cover (EVC), existing vegetation height (EVH), and biophysical setting (BpS). For a more detailed description of the calibration workshop see the Local Fuel Calibration Report by Helmbrecht and Scott (2010). Slope, aspect and elevation were taken from LANDFIRE’s base layers (LANDFIRE National) without adjustment. We also used LANDFIRE National without adjustment for vegetation height and cover of shrub and grass lifeforms. We reduced vegetation cover of the tree lifeform (forest canopy cover) using the recommended procedure posted on the LANDFIRE website (LANDFIRE 2010a).

A geospatial layer of surface fuel model was created at the local calibration workshop. At the workshop we reviewed and edited the LANDFIRE fuel mapping rules for the dominant mapping zone covering the forest. The mapping rules are a lookup table based on EVT, EVC, EVH and BpS. At the calibration workshop we used the LANDFIRE National (ca. 2000) EVT, EVH and

BpS layers. We used the LADNFIRE National EVC layer for herbaceous and shrub life forms, but substituted our adjusted canopy cover values for the tree life form. The calibration process produced a ca. 2000 fuel model layer.

A canopy bulk density layer was generated using a general linear model (GLM) produced by LANDFIRE (Reeves et al. 2009). The GLM is not used in current published LANDFIRE data, but will be used in future LANDFIRE products. The GLM is essentially a non-linear regression of canopy bulk density against forest canopy cover and height. The data used to create the GLM came from the LANDFIRE Reference Database (LFRDB) (LANDFIRE 2010b).

A canopy base height layer was produced using a new mapping method produced by LANDFIRE. Like the GLM for canopy bulk density, the new canopy base height mapping method is not used in currently published LANDFIRE data but will be used in future LANDFIRE data products such as LANDFIRE refresh. It is also available in the newly released Total Fuel Change Tool, ToFuΔ, developed by the LANDFIRE program.

To bring the landscape forward to 2009, we needed to update for wildfires that occurred between 2000 and 2009, and for the ongoing insect infestation. Areas that experienced a wildfire during that time were identified using fire severity data from the Monitoring Trends in Burn Severity (MTBS) program (MTBS 2010). TEAMS analysts and the BDNF fire and fuel staff created a lookup table that identified a post-fire fuel model as a function of EVT, fire severity (three classes) and time since fire (1-5 years, 6-10 years). Forest vegetation height was assumed to remain unchanged after low and moderate severity fire, but canopy cover, canopy base height and canopy bulk density were reduced to a specified fraction of the pre-fire level. All canopy characteristics were set to zero in the case of high (stand-replacement) severity fire.

Finally, it was necessary to adjust the ca. 2000 landscape to reflect changes that have taken place due to the ongoing insect outbreak on the forest. A procedure very similar to the wildfire update was used. In place of the MTBS fire severity data used for the wildfire update, we used geospatial data of relative overstory canopy loss produced by Region 1 Geospatial Services Group (figure 2). Their data classified the relative amount of canopy cover reduction from 2000 to 2009 (Ahl et al. 2010). We created an expert-opinion lookup table based on the pre-infestation fuel model and relative canopy loss class to estimate the surface fuel model as of 2009 (figure 3). Canopy height and canopy base height were assumed to remain unchanged following the outbreak, the rationale being that canopy height is an average value and has a marginal effect on fire behavior and that the beetles typically do not affect the smaller trees that contribute most to canopy base height. Canopy bulk density (figure 4) and canopy cover (figure 5) were reduced in proportion to the Region 1 canopy loss values.

The effects of insect infestations on fuel and fire behavior vary with time since disturbance. Early in the infestation the surface fuel model and most canopy characteristics remain unchanged, but the reduced moisture content of the foliage temporarily increases the likelihood of crown fire. This is called the “red phase” of the infestation. We did not simulate this phase because it is of relatively short duration at any given place on the landscape, usually 3-5 years. Instead, we simulated the longer-duration standing-gray phase during which the foliage and fine branches of dead trees have fallen to the ground—so canopy bulk density is reduced and surface fuel is slightly increased—but the dead trees remain standing with most of their branchwood still attached. Decades after the outbreak these dead trees will be falling to the ground, exacerbating fuel consumption, smoke production, and resistance-to-control in the event of a wildfire. We did not simulate this later phase of the current outbreak.

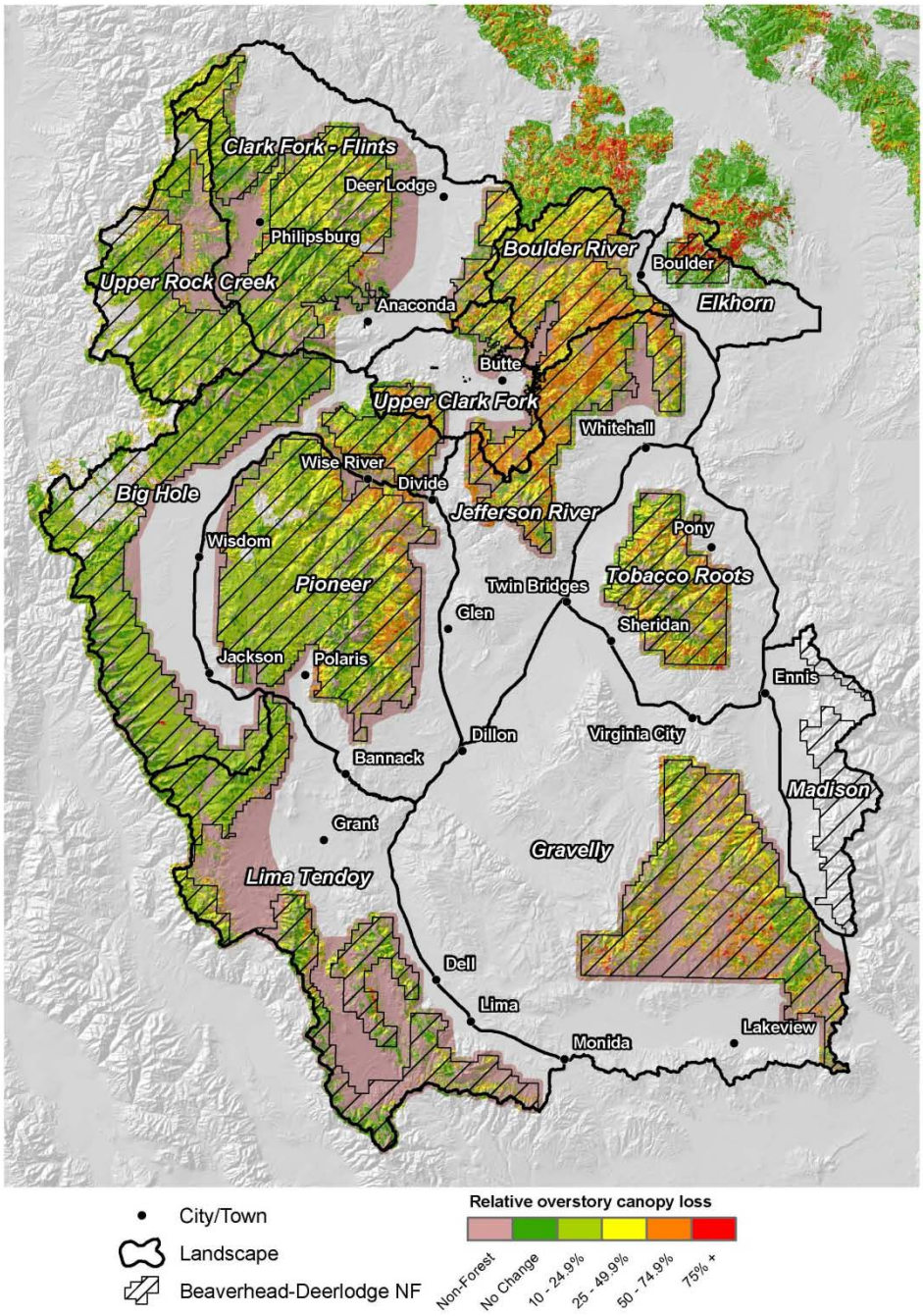

Figure 2. Map of relative overstory canopy loss data, 2000-2009. Canopy loss data were clipped to a buffer around the Forest boundary, and therefore does not include all forested land within the analysis area. No relative canopy loss information was developed for the Madison landscape (SE corner). A different canopy loss method was used on the Helena National Forest (NE corner), resulting in a discontinuity of canopy loss data across the Forest boundary.

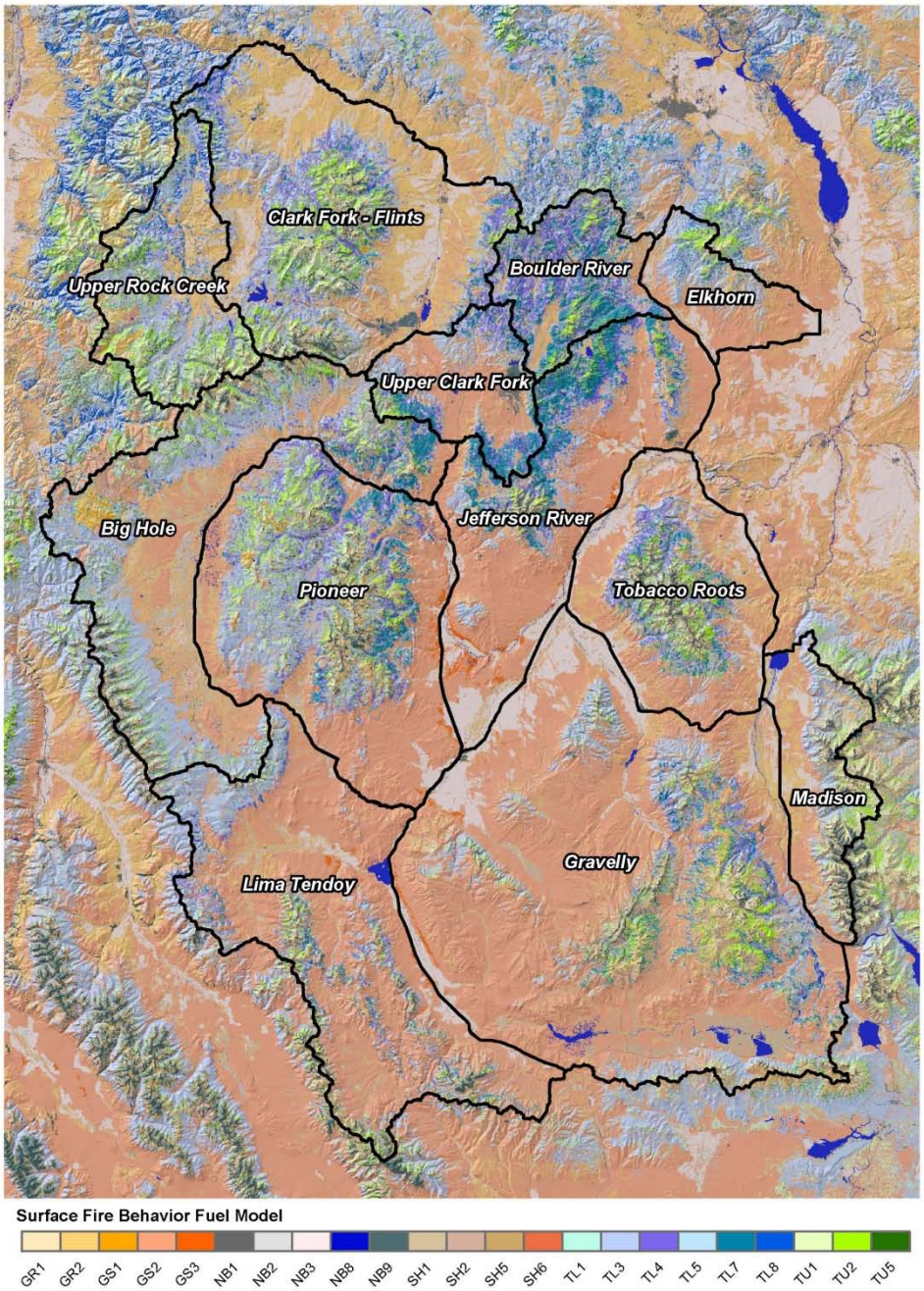

Figure 3. Map of surface fire behavior fuel model for the 2009 landscape condition.

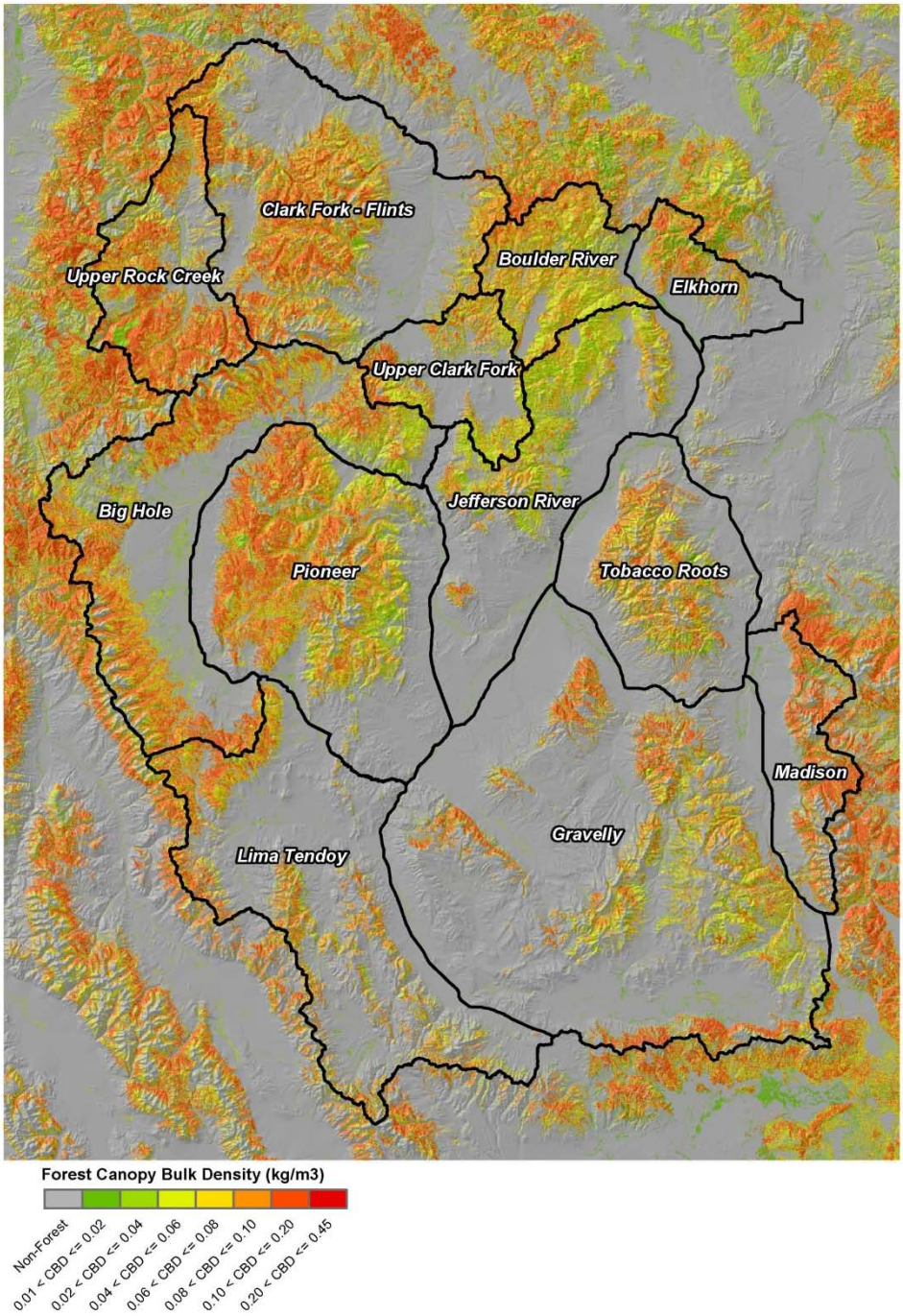

Figure 4. Map of forest canopy bulk density for the 2009 landscape condition.

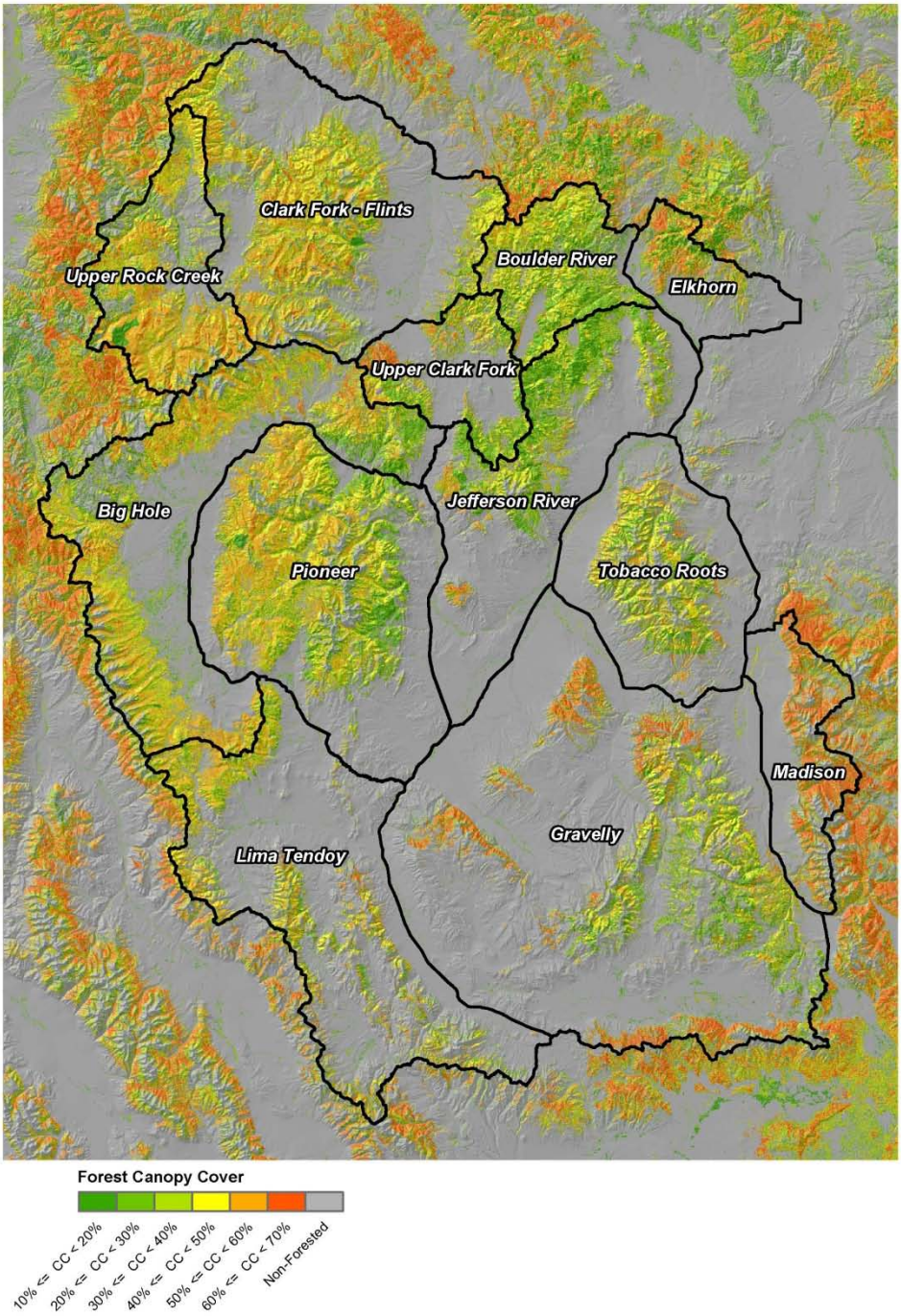

Figure 5. Map of forest canopy cover as for the 2009 landscape condition.

End-of-outbreak landscape data

A hypothetical end-of-outbreak fuel condition was generated by simulating the effects of beetles on relative overstory canopy loss using the Forest Vegetation Simulator on 448 forested plots gathered on the BDNF (See Appendix B for details). The plots were sorted into VMAP cover type classes, then the mean relative canopy loss was calculated for each VMAP class. Consistent geospatial data was not available for VMAP, so the plot results were cross-walked to combinations of LANDFIRE existing vegetation type, existing vegetation height, and environmental site potential. The cross-walked canopy loss was then applied geospatially to the LANDFIRE vegetation data. However, the estimated 2009 relative canopy loss was retained if it was greater than the hypothetical end-of-outbreak canopy loss. Therefore, the end-of-outbreak canopy loss data estimates the increased extent and intensity of beetle effects on forest vegetation (figure 6). This hypothetical canopy loss dataset was then processed in the same manner as the 2009 canopy loss dataset to produce data layers representing end-of-outbreak fuel model (figure 7), canopy bulk density (figure 8) and canopy cover (figure 9).

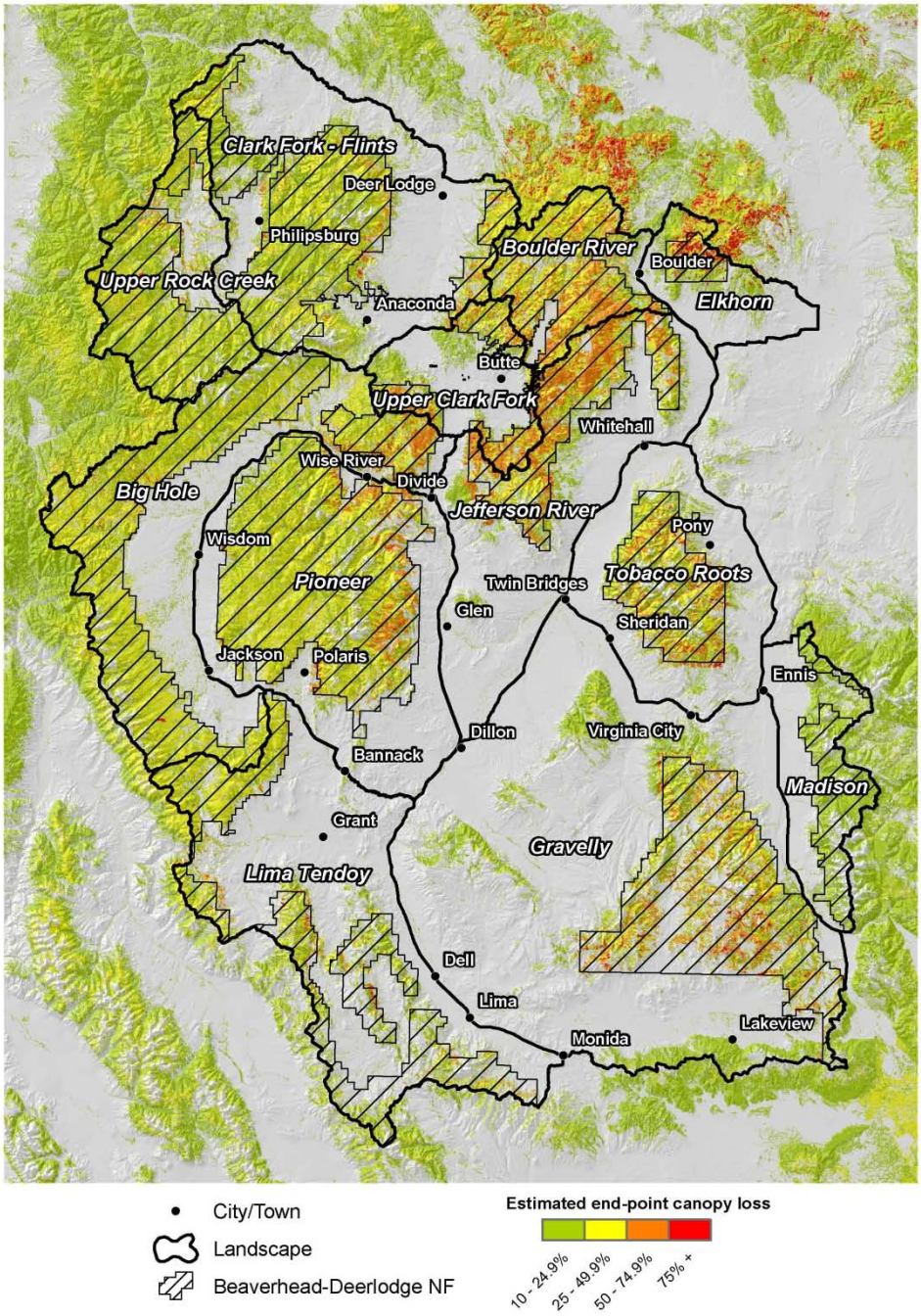

Figure 6. Map of estimated end-of-outbreak relative canopy loss.

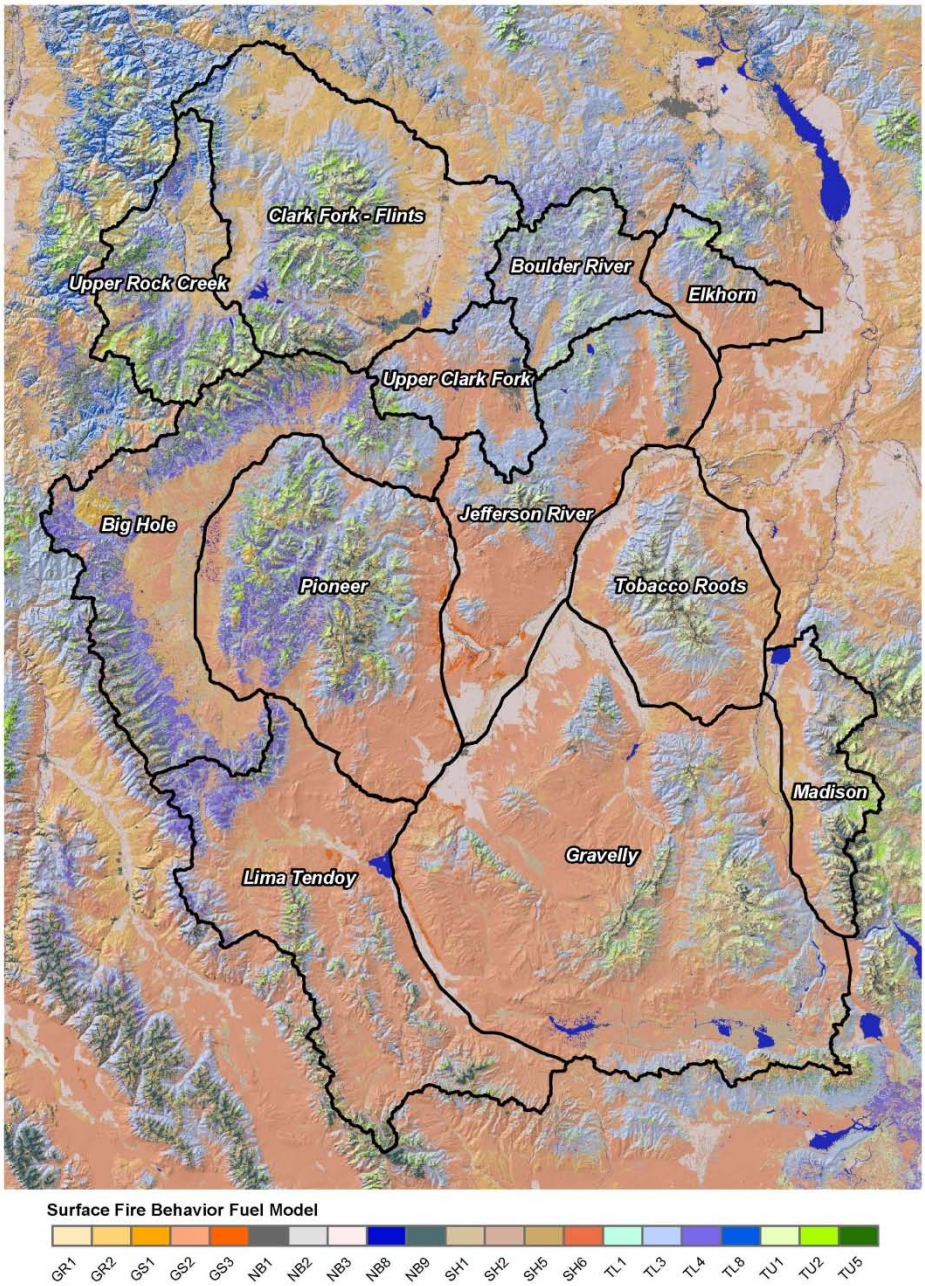

Figure 7. Map of surface fuel model for the hypothetical end-of-outbreak landscape condition.

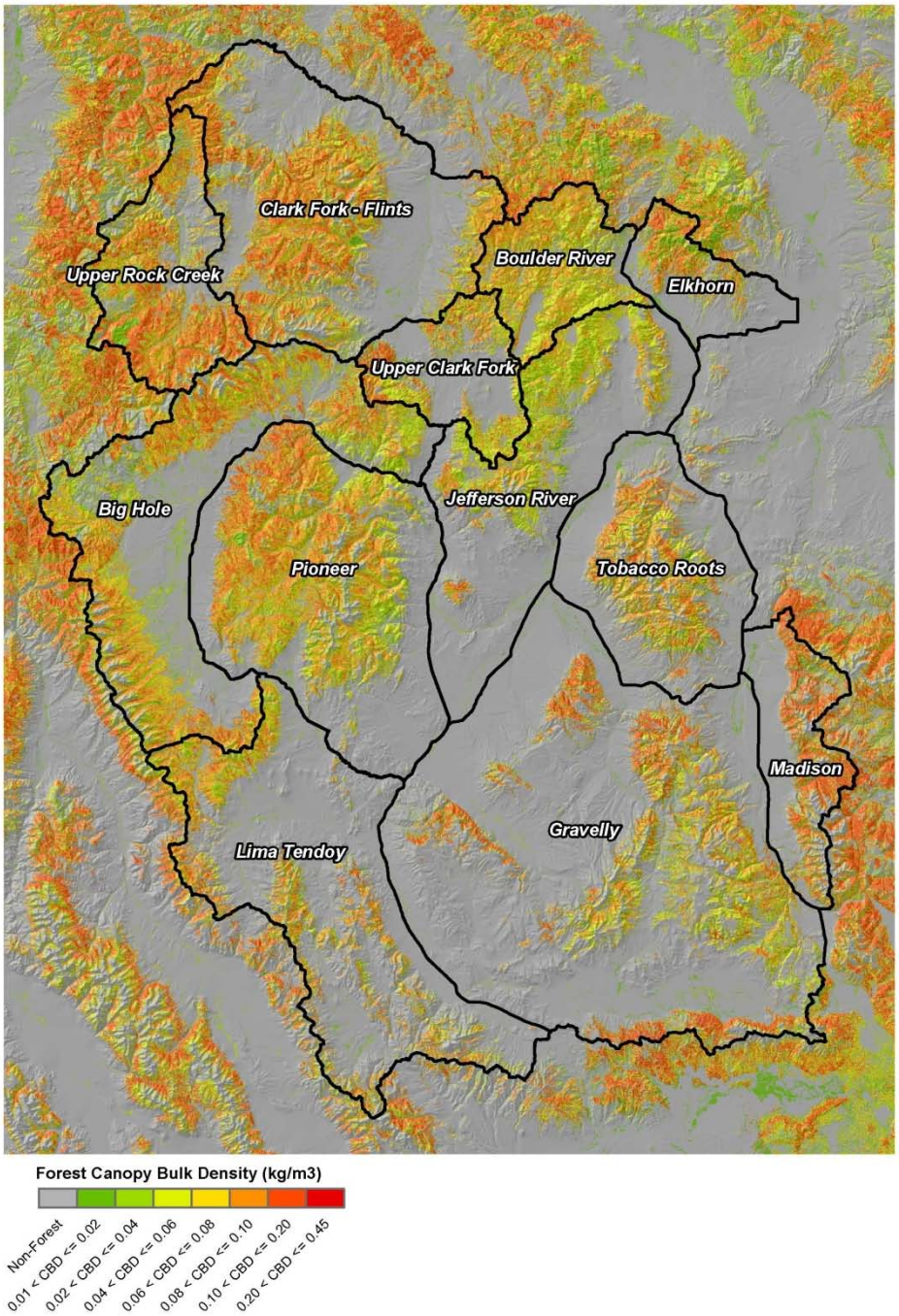

Figure 8. Map of surface canopy bulk density for the hypothetical end-of-outbreak landscape condition.

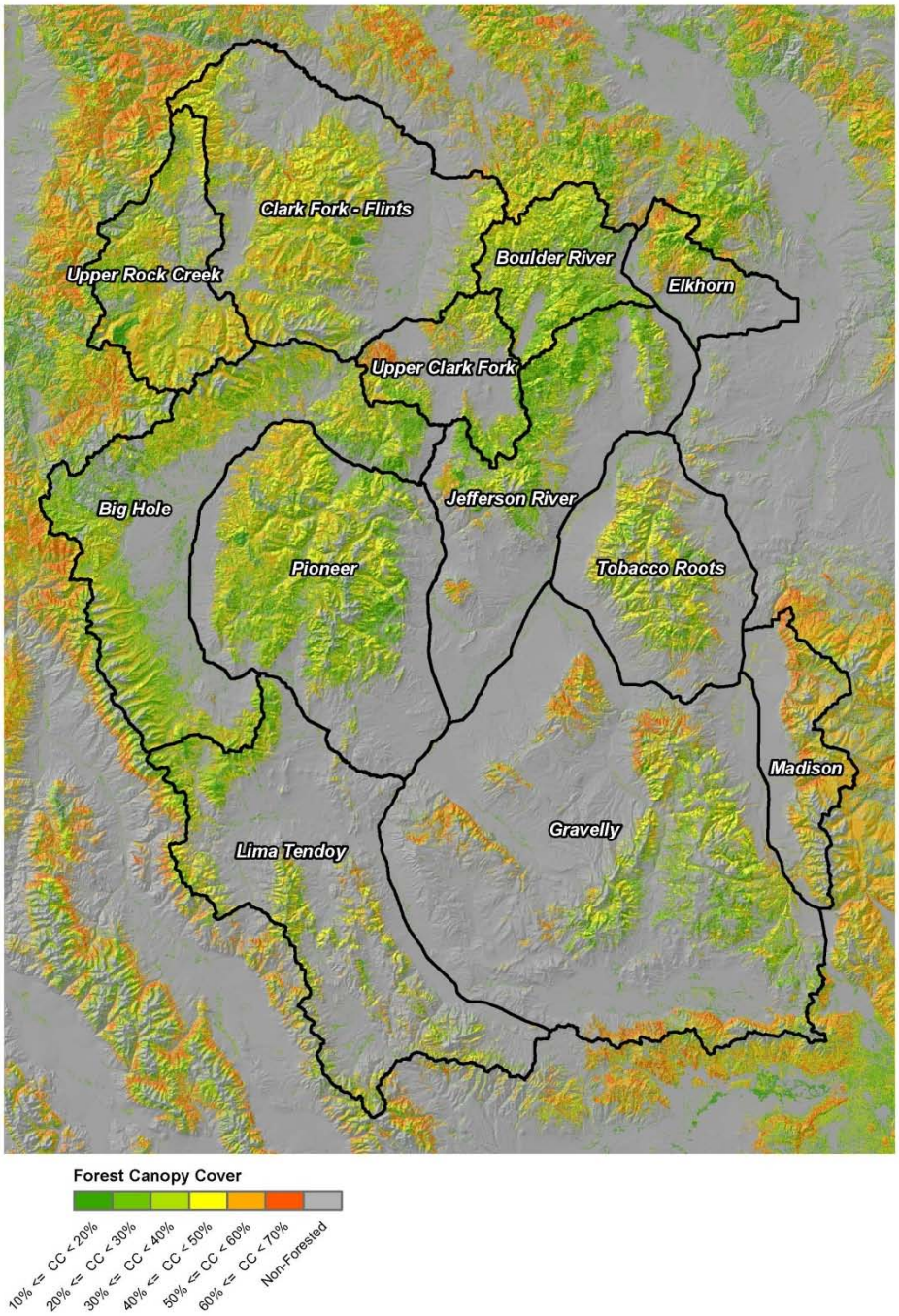

Figure 9. Map of surface forest canopy cover for the hypothetical end-of-outbreak landscape condition.

Fire danger data

In FireFamilyPlus we identified the weather stations from across the forest that have consistent hourly wind and daily fire weather observations and created a "special interest group", or SIG. The SIG consisted of the PBURG, GALENA, WISE RIVER, FRENCH CREEK, and ENNIS stations. From the SIG we produced a composite trend of energy release component (ERC) throughout a year (figure 10).

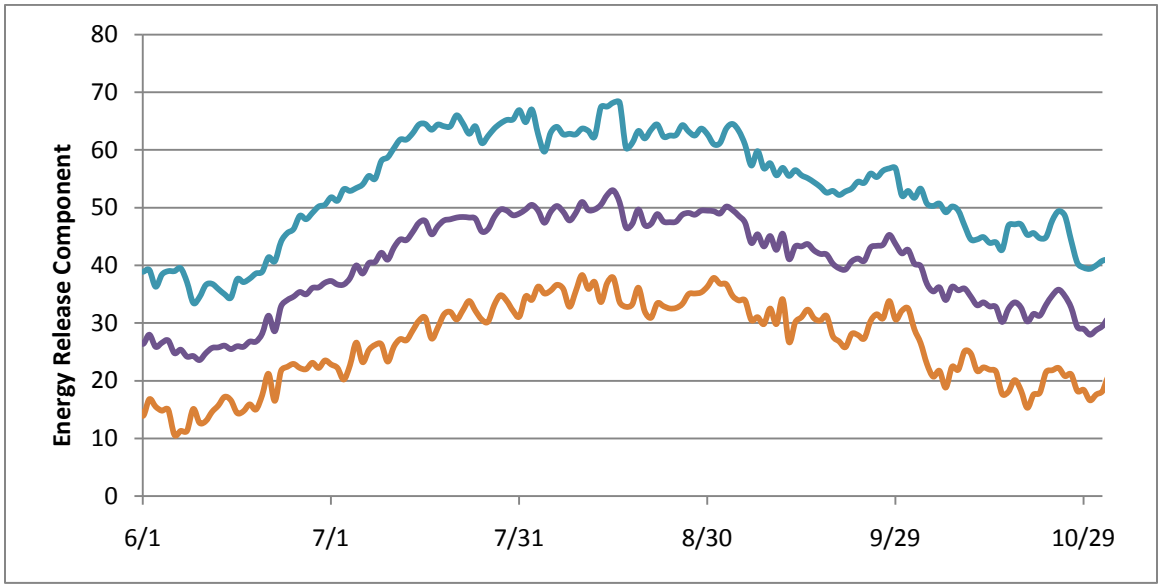

Figure 10. Fire-season trend of Energy Release Component for NWCG fuel model g (ERCg) for the BDNF special interest group of five weather stations. The middle line represents the mean ERC for each day of the fire season. The upper and lower lines represent the mean plus-or-minus one standard deviation.

The bounding lines indicate the +/- 1 standard deviation from the average. This information is used by FSIM to produce artificial ERC traces for a season. Those artificial seasons can have ERC values that exceed the average by two or more standard deviations to represent extreme ERC values. The fire danger records for the SIG were used to associate ERC with surface fuel moisture content.

Fire occurrence data

FSIM requires information regarding the occurrence of fire in the analysis area, specifically large fires—those that escape initial attack and require extended suppression response. For this analysis we defined a large fire as one greater than 300 acres in final fire size. We gathered fire occurrence data for all jurisdictions in the analysis area. Those data include fires that occur well outside the analysis area, so we clipped to the analysis area. A total of 82 large fires occurred in the analysis area between 1990 and 2009; those fires started on 65 days (some days had multiple fire starts). We used FireFamilyPlus to construct a logistic regression model of the probability of a large-fire day within the 15 million acre fire modeling area. A large-fire day is a day on which one or more fires start (or is discovered) and eventually burns more than 300 acres. The logistic regression model for this assessment's fire modeling area is

$$P(\text{Large-fire day}) = 1 / (1 + \exp(-1 * -8.4049 + (-1 * 0.0855) * ERC))$$

A graphical representation of the above equation is shown in figure 11 below, which shows a very large range of ERC values. For reference, the maximum observed ERC in the database is 96, the 95th percentile ERC is 61, and the 90th percentile ERC is 54. In other words, the probability of a large-fire day is less than 0.02 percent—1 in 5000—on 90 percent of the fire-season days.

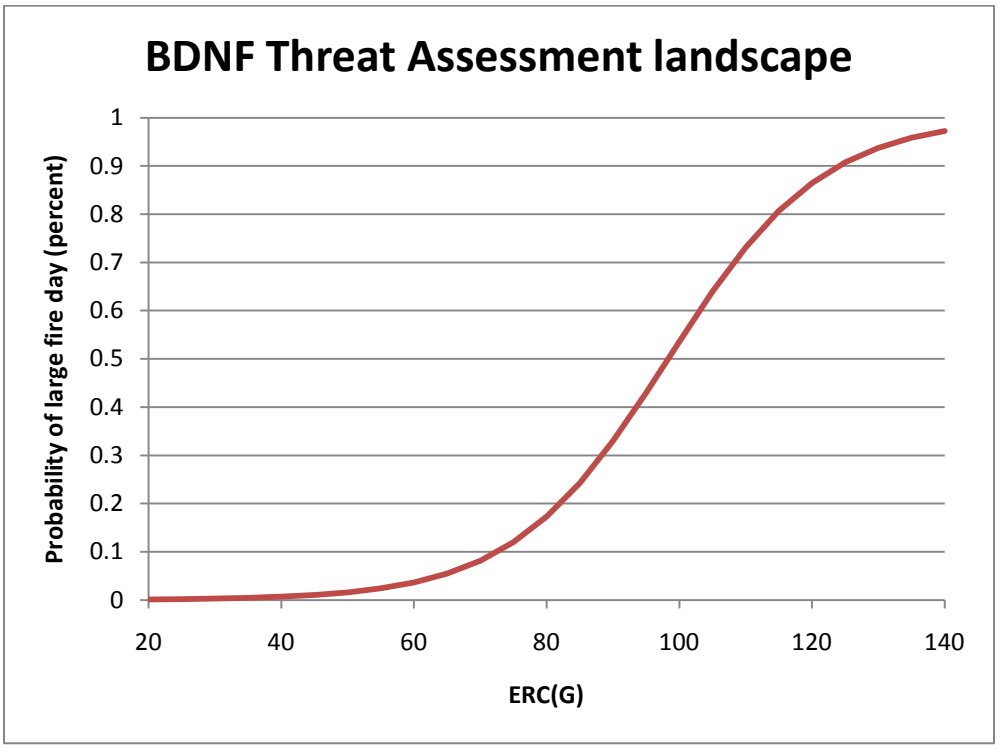

Figure 11. Graphical representation of the logistic regression equation for the probability of a large-fire day (> 300 ac.) occurring somewhere on the 15 million acre fire modeling area. For reference, the maximum observed ERC in the database is 96, the 95th percentile ERC is 61, and the 90th percentile ERC is 54.

We also determined the distribution of number of fires started on each of the 65 large-fire days. During the last 19 years on the fire modeling area, only one large-fire started on 58 of the 65 large-fire days in the record (89%), two fires started on 5 of the days, four on one day (July 23, 2000), and ten also on one day (July 31, 2000).

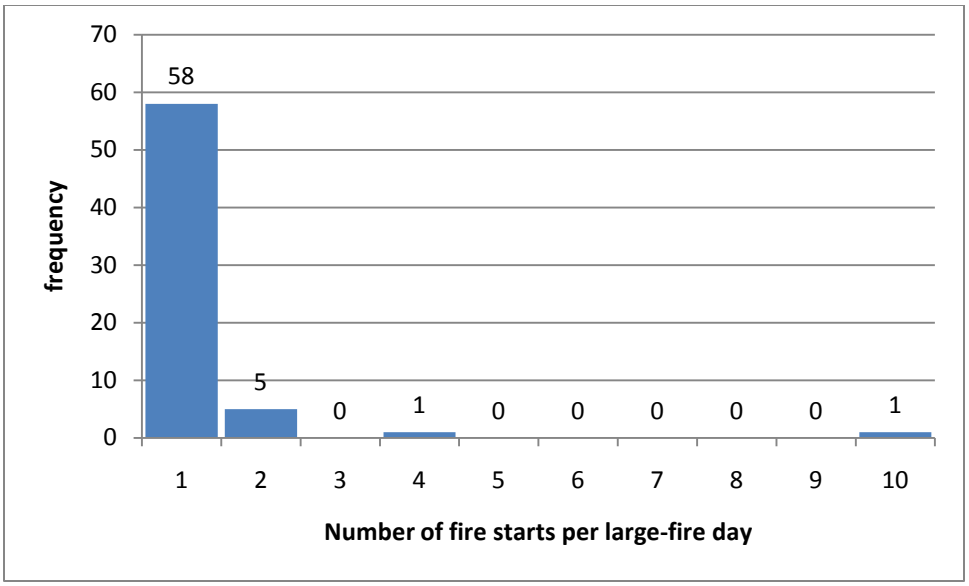

Figure 12. Distribution of the number of large-fire starts per large-fire day. Four fires were discovered in the fire modeling area on July 23, 2000, and ten fires were discovered on July 31, 2000.

Fire occurrence is not uniform across the fire modeling area. To account for that non-uniformity, FSIM uses a geospatial layer indicating relative ignition density across the landscape, and will randomly locate fires according to this density grid during simulation. The ignition location of all 82 large fires in the analysis area is shown in figure 13.

Because FSIM is concerned only with large fires, and due to the relatively infrequent occurrence of large fires on the landscape, we used a nationwide large-fire ignition density grid created at the Missoula Fire Sciences Lab based on a 75 km average density (and a cell size of 20 km). The highest density of large-fire starts is found in the NW corner of the analysis area (figure 13). The SE corner has a moderate density of large-fire starts. The lowest density of large-fire starts occurs along a SW to NE line running though the center of the analysis area. On a highly variable landscape like the BDNF, which includes forested mountains and grassland valley-bottoms, such a coarse-scale ignition density grid tends to wash out the fine-scale patterns that occur. In this case, the supplied ignition density grid indicates a higher propensity to start large fires in the valley-bottom grasslands than the historic locations would indicate appropriate. In lieu of developing a custom CART model or logistic regression specifically for this analysis, we instead simply identified the valley-bottom grasslands within the fire modeling area and set the ignition probability to a very low value (but not zero).

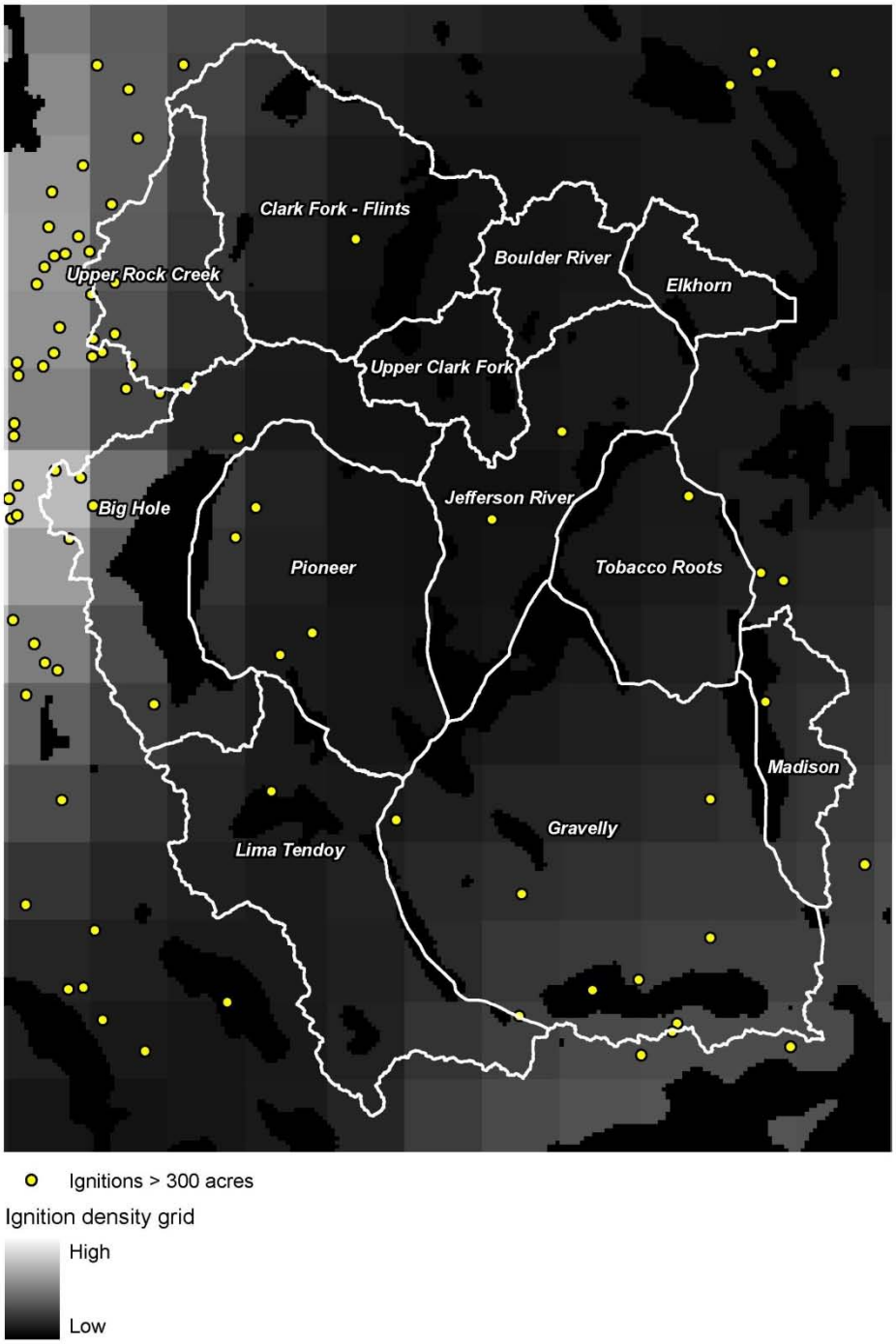

Figure 13. Start locations of fires greater than 300 acres (yellow dots) that occurred within the fire modeling area from 1990 to 2009, and the ignition density grid created from them at a nationwide scale. To prevent FSIM from starting large fires in valley-bottom locations, we created a valley-bottom mask and artificially lowered the ignition density in those locations to near zero.

The FSIM simulations produce an ASCII grid that we split into six geospatial layers, each of which represents the burn probability for a specific fire intensity level (FIL). Adding the six separate BP values for a given pixel produces the total BP for a single fire season. FSIM also produces a grid representing the mean fireline intensity (MFI) at each pixel. Taken together, those

two factors together characterize wildfire hazard. To create a single map of wildfire hazard we multiplied BP by MFI. Higher values in that resulting grid are associated with both high BP and high MFI—therefore high wildfire hazard—and lower values are associated with low BP and low MFI.

The six separate BP grids are used in the calculation of wildfire threat, which is described in the Calculating Wildfire Threat and Benefit section below.

Mapping key resources

The BDNF Forest Plan identifies 10 key resources to protect on enhance on the Forest:

- Municipal watersheds
- Residential structures
- Utility infrastructure
- Vegetation resiliency
- 303(d)-listed streams
- Recreation infrastructure
- Threatened and Endangered species (occupied grizzly habitat)
- Isolated TES fish populations
- Non-isolated bull trout and cutthroat trout populations
- Elk winter range

To obtain more precision in the application of response functions, many of these key resources were divided into sub-resources. Municipal watersheds and 303(d)-streams were both divided into direct and indirect effects. Direct effects were mapped as a 150-foot buffer around the watercourse; indirect effects were mapped as the remaining portion of the watershed. Residential structures were divided into two density classes because the wildfire threat to structures is directly proportional to the density of structures in an area. Utility infrastructure information was available separately for power transmission lines and for communication sites. Vegetation resiliency was divided into three classes: whitebark pine, conifer-encroached rangelands, and Douglas-fir/ponderosa pine stands. Recreation infrastructure was divided into ski areas, high-investment recreation sites (e.g. interpretive centers), and general recreation sites (e.g. trailheads). The only geospatial information available for threatened and endangered species was for occupied grizzly habitat, so only that TES species was included in this assessment. Other TES and sensitive species may also be threatened by wildfire. The wildfire threat to those species can be included in a wildfire threat assessment when information regarding their location and susceptibility to wildfire (response function) is available. The final three resources were not divided.

TEAMS worked with BDNF GIS and resource staff to develop or obtain and critique existing geospatial data for each of these key resources. All geospatial data were converted to raster format for use in calculating wildfire threat.

Susceptibility of key resources

Response functions

The relative response to wildfire (net value change) of 10 key resources was quantified by BDNF resource staff in the form of a tabular relative response function for each resource. The response

function values (RFVs) reflect the relative net change in value of a unit area of the key resources if it burns in each of six fire intensity levels (FILs). Positive RFVs indicate a benefit, or increase in value; negative RFVs indicate a loss, or decrease in value. RFV_{ij} is the response function value for the ith FIL and the jth key resource. Response function values ranged from -100 (greatest possible loss of resource value) to +100 (greatest increase in value).

BDNF staff designed a custom response function for each key resource (table 1), subdividing many of the resources so that different response functions or different weights could be applied to each sub-resource.

Table 1. Baseline tabular response functions for each key resource. Response function values represent the net percentage change in value of the resource for a given fire intensity level. Negative numbers indicate a loss of value; positive numbers indicate an increase in value.

HVRA	Sub-HVRA	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Municipal Watershed	Direct effects	20	0	-40	-60	-80	-100
Municipal Watershed	Indirect effects	0	0	0	-20	-40	-60
Residential structures	Low density	-10	-30	-50	-90	-100	-100
Residential structures	High density	-10	-30	-50	-90	-100	-100
Utility Infrastructure	Transmission lines	10	10	10	-40	-80	-100
Utility Infrastructure	Communication towers	10	10	10	-40	-80	-100
Vegetation Resiliency	Whitebark pine	0	10	30	50	70	0
Vegetation Resiliency	Encroached rangelands	10	30	70	50	30	10
Vegetation Resiliency	D-fir/Ponderosa pine	40	60	20	-20	-60	-80
303(d)-listed streams	Direct effects	20	0	-40	-60	-80	-100
303(d)-listed streams	Indirect effects	0	0	0	-20	-40	-60
Rec. Infrastructure	Ski areas	20	10	-20	-40	-60	-80
Rec. Infrastructure	High investment	10	-20	-50	-90	-100	-100
Rec. Infrastructure	Normal investment	10	-20	-50	-90	-100	-100
TES (Grizzly habitat)	--	10	20	20	0	-15	-40
Isolated TES fish	--	35	40	0	-50	-80	-100
Non-isolated trout	--	35	40	0	-35	-60	-85
Elk winter range	--	10	15	25	-20	-40	-60

Weighting key resources

The above response functions can be applied as-is to each key resource individually, but doing so without modification does not allow the individual responses to be added into an overall response to all resources. Summing the response to wildfire across all key resources requires an estimate of the relative importance of each resource to the others. This was accomplished by Forest staff and edited by the Forest FLT at the response function workshop. First, the most important resources on the Forest were identified and given a Relative Importance value of 1. Municipal watersheds, residential structures and utility infrastructure were judged to be the most important resources on the Forest, so all three were given RI values of 1.

Next, RI values were assigned to each of the remaining key resources. Vegetation resiliency was given a value of 90, meaning that, overall on the whole Forest, maintaining and improving the three vegetation resiliency sub-resources is 90 percent as important as each of the top three resources. Staff also assigned a relative importance value to each of the sub-resources. These

values, shown in parentheses in table 2 below, represent the share of the key resource's overall importance.

The relative importance values apply to the overall resource on the Forest as a whole. The calculations need to take into account the relative extent of each resource to avoid overemphasizing resources that cover many acres, such as 303(d)-listed streams. This was accomplished by noting the relative extent (RE) of each resource on the forest. Here, RE refers to the number of pixels (in thousands) mapped to each resource. The relative importance of each resource is spread out over each resource's extent. A resource with few pixels can have a high importance per pixel; a resource with a great many pixels has a low importance per pixel.

Table 2. Relative importance assignments for each resource and sub-resource (in parentheses), and the relative extent of each resource and sub-resource (thousands of 30-m pixels).

HVRA	Sub-HVRA	Relative Importance (RI)	Relative Extent (RE)
Municipal Watershed	Direct effects	100 (80)	53.62
Municipal Watershed	Indirect effects	100 (20)	291.5
Residential structures	Low density	100 (70)	6206
Residential structures	High density	100 (30)	748.3
Utility Infrastructure	Transmission lines	100 (95)	60.86
Utility Infrastructure	Communication towers	100 (5)	0.0200
Vegetation Resiliency	Whitebark pine	90 (40)	234.6
Vegetation Resiliency	Encroached rangelands	90 (30)	668.8
Vegetation Resiliency	D-fir/ Ponderosa pine	90 (30)	4848
303(d)-listed streams	Direct effects	70 (80)	639.5
303(d)-listed streams	Indirect effects	70 (20)	24120
Rec. Infrastructure	Ski areas	70 (60)	10.26
Rec. Infrastructure	High investment	70 (30)	0.1190
Rec. Infrastructure	Normal investment	70 (10)	0.1670
Grizzly habitat (TES)	--	60 (100)	1560
Isolated TES fish	--	40 (100)	38.32
Non-isolated trout	--	10 (100)	553.9
Elk winter range	--	10 (100)	7321

Calculating wildfire threat and benefit

The resulting effective response functions were combined with wildfire hazard information generated by FSIM, which estimates the annual burn probability by FIL. Net wildfire response for each key resource ($Response_j$), whether threat or benefit, was quantified as the expected value of net wildfire response at each pixel on the landscape. This was calculated as the sum-product of burn probability (BP) and wildfire response (RF) over all fire intensity levels (FILs), with adjustments for the relative importance and relative extent of each key resource

$$Response_j = \sum_{i}^{n} BP_i * RFV_{ij} * RI_j / RE_j$$

where *i* refers to fire intensity level (FIL; n = 6), *j* refers to each of the 10 key resources, *RI* is the relative importance of the resource and *RE* is its relative extent (number of pixels). The expected response calculation shown above places each pixel of each resource on a common scale, allowing them to be summed across all resources.

$$OverallResponse = \sum_{j}^{m} Response_j$$

The overall response – threat or benefit – applies to each pixel in the analysis area. The threat and benefit data were summarized into charts by summing the pixel-level threat results across each BDNF landscape and across the whole analysis area.

Results

The following sections contain whole-forest results for wildfire hazard and threat in the analysis area. Hazard and threat results for the individual BDNF landscapes were presented in the fire and fuels section of the Management Opportunity Scenario (MOS) reports. Please see the individual MOS reports for detailed information regarding hazard and threat on each BDNF landscape.

Wildfire hazard and threat results are first reported for the 2009 landscape condition, for which we have reasonable confidence in the geospatial fuel characteristic data. Following that is a short section reporting how wildfire hazard and threat may change compared to the 2009 condition. Note that the end-of-outbreak condition reports results for a hypothetical landscape condition; it is not a prediction of where the extent and intensity of the beetle outbreak will occur.

2009 landscape condition

The following two sections present wildfire hazard and threat results for the 2009 landscape condition.

Wildfire hazard

Wildfire hazard is characterized by three FSIM results: burn probability (BP), mean fireline intensity (MFI), and “hazard”, the product of BP and MFI. We used FSIM to simulate 40,000 iterations of a fire season. Burn probability is the annual probability that an individual landscape pixel will experience a wildfire. Burn probability is calculated as the number of times a pixel is burned during any of the iterations divided by 40,000, the total number of iterations. Mean fireline intensity is the arithmetic mean fireline intensity (kW/m) of the simulations that a pixel did experience a wildfire. These two factors taken together characterize wildfire hazard at a pixel. For a single measure of wildfire hazard, we multiply these two results together. Pixels with high BP and high MFI have high wildfire hazard; pixels with low BP and low MFI have low wildfire hazard.

A map of annual burn probability over the whole analysis area is shown in figure 14.

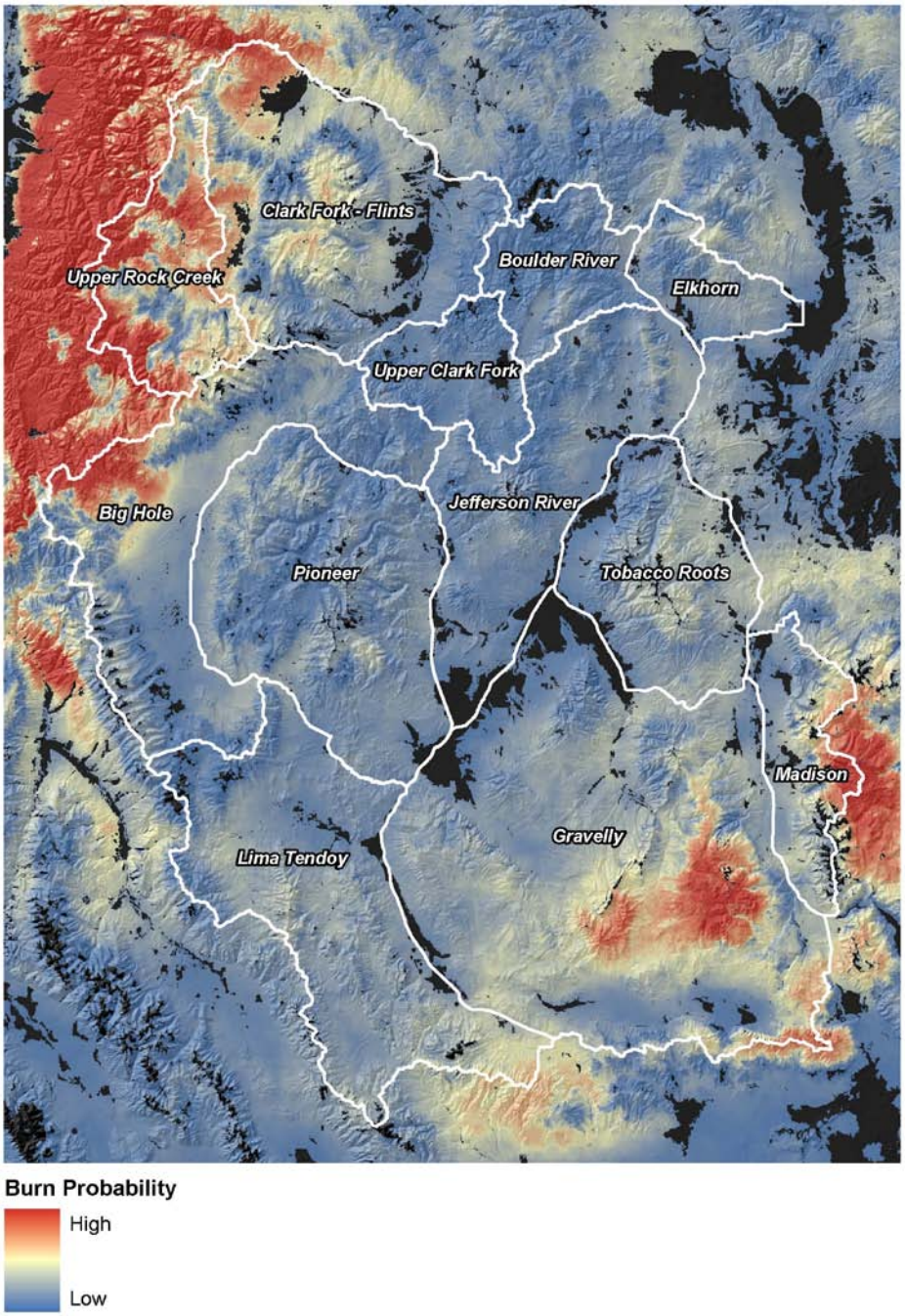

Figure 14. Annual burn probability on the BDNF fire modeling area. Areas in black are non-burnable.

The regions of the landscape with the highest annual burn probabilities—the NW and SE portions of the landscape—correspond to the regions with the highest ignition density. Burn probabilities are lowest in a SW-NE band that corresponds to low ignition density.

A map of mean fireline intensity is shown in figure 15 below.

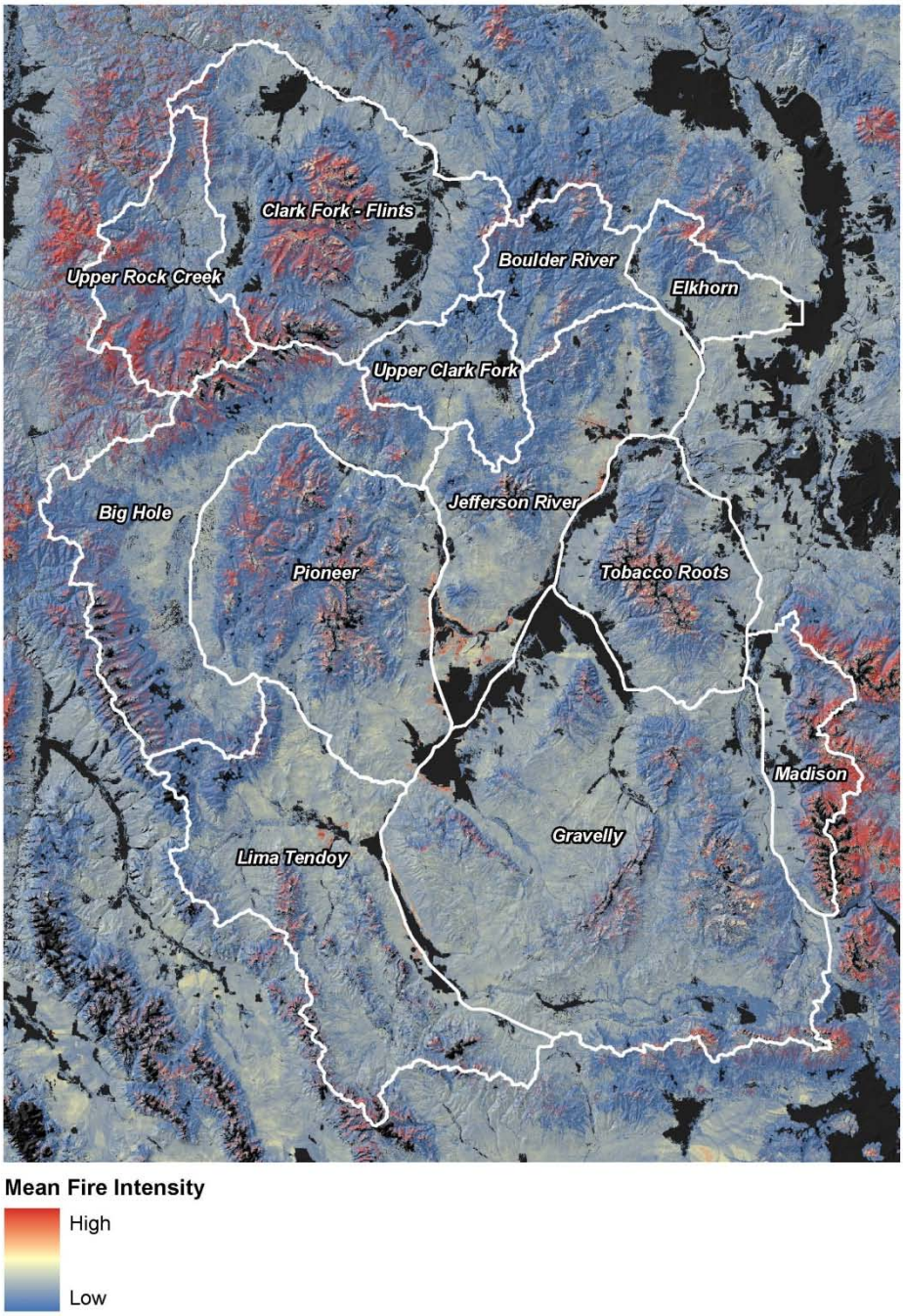

Figure 15. Map of mean fireline intensity on the BDNF fire modeling area. Areas in black are non-burnable.

Generally, forests less impacted by the beetles, like the Clark Fork-Flints landscape, exhibit higher mean fire intensity values than those heavily impacted, such as the Boulder River landscape. Valley-bottom grasslands exhibit moderate MFI values compared to much of the beetle-impacted forests, but the intact forests produce the highest MFI values in the fire modeling area.

A map of overall wildfire hazard is shown in figure 16 below.

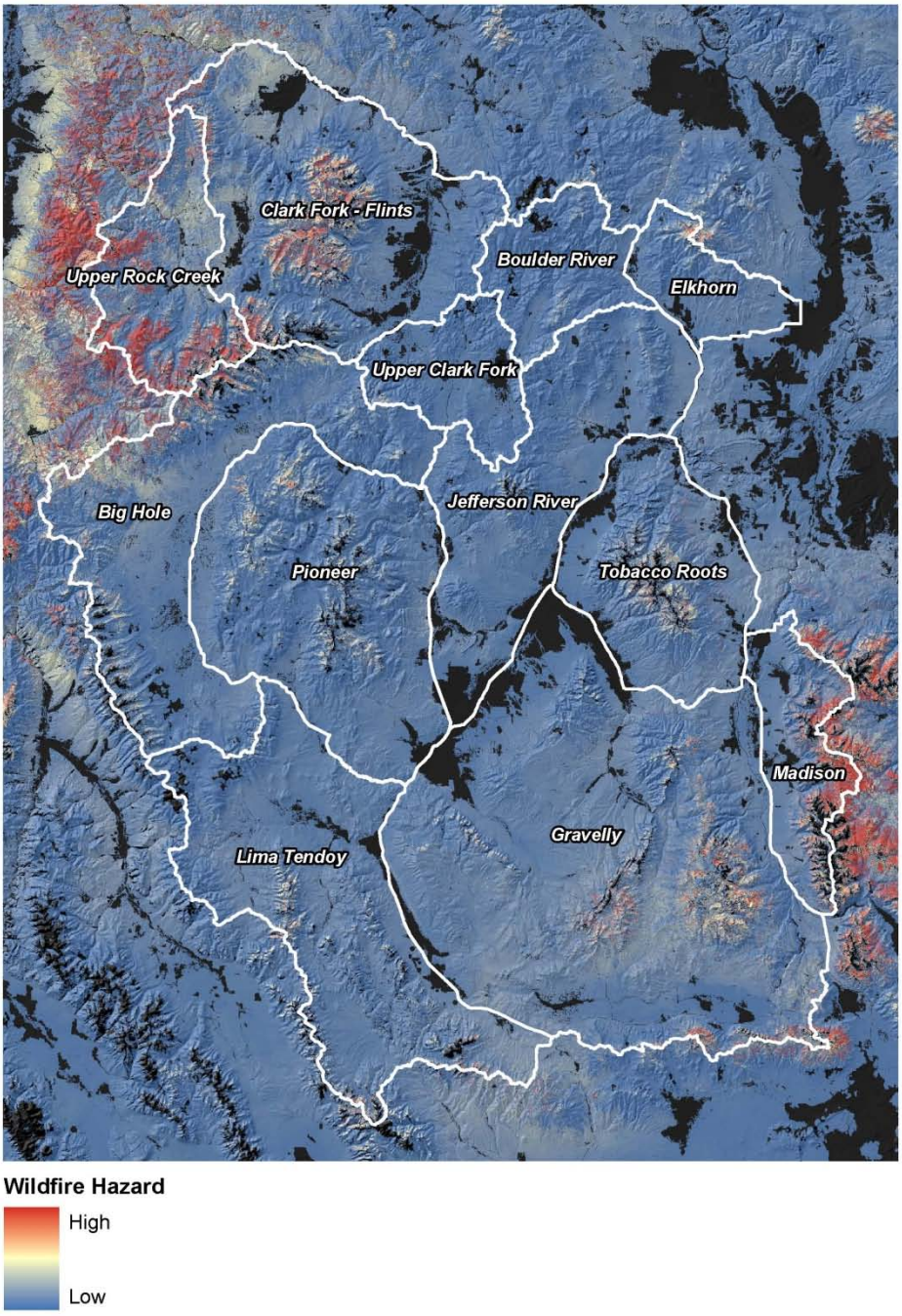

Figure 16. Map of overall wildfire hazard on the BDNF fire modeling area, expressed as the product of burn probability and mean fireline intensity. Areas in black are non-burnable.

The areas of greatest overall hazard occur where both BP and MFI are high—the dense forests of the NW and SE corners of the analysis area.

In addition to the map outputs, FSIM also provides the information needed to produce a fire-size distribution for the fire modeling area (figure 17). Seven percent of the fires never reached 10 acres in size, and 21 percent were between 10 and 100 acres final fire size. Nearly one-third of the

fires reached between 100 and 1,000 acres, and another third were between 1,000 and 10,000 acres final fire size.

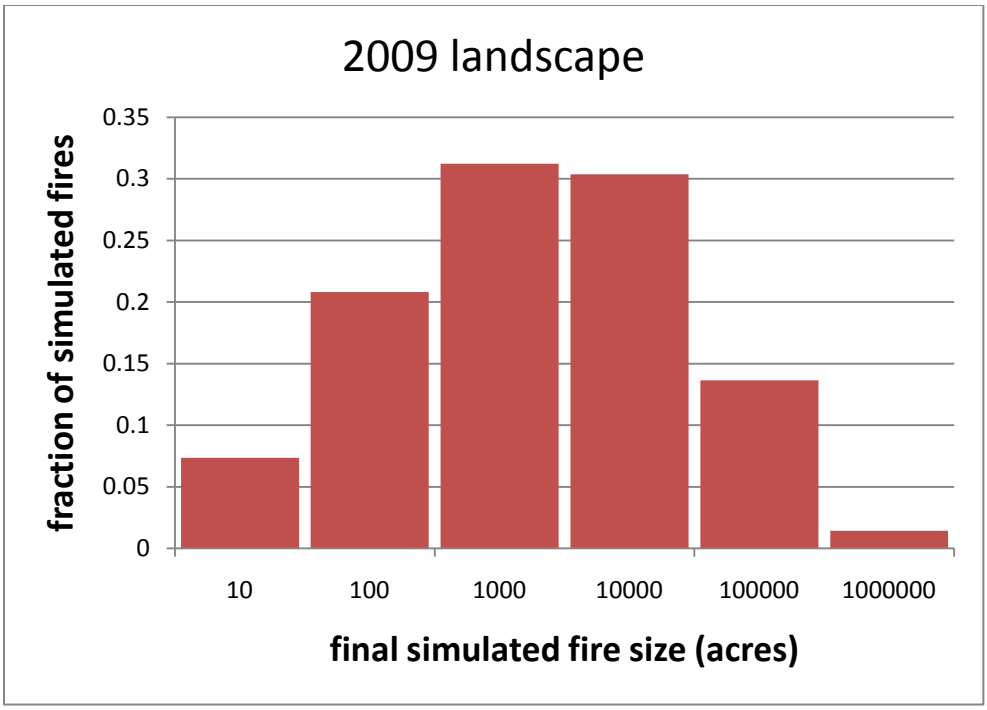

Figure 17. Simulated fire-size distribution on the BDNF fire modeling area. (Log scale on the fire-size axis)

Wildfire threat

The simplest assessment of the wildfire threat to key resources is to count the number of key resources present on each pixel—the more key resources present at a point, the greater the potential wildfire threat at that point. Figure 18 summarizes the number of overlapping key resources present on each acre of the BDNF analysis area.

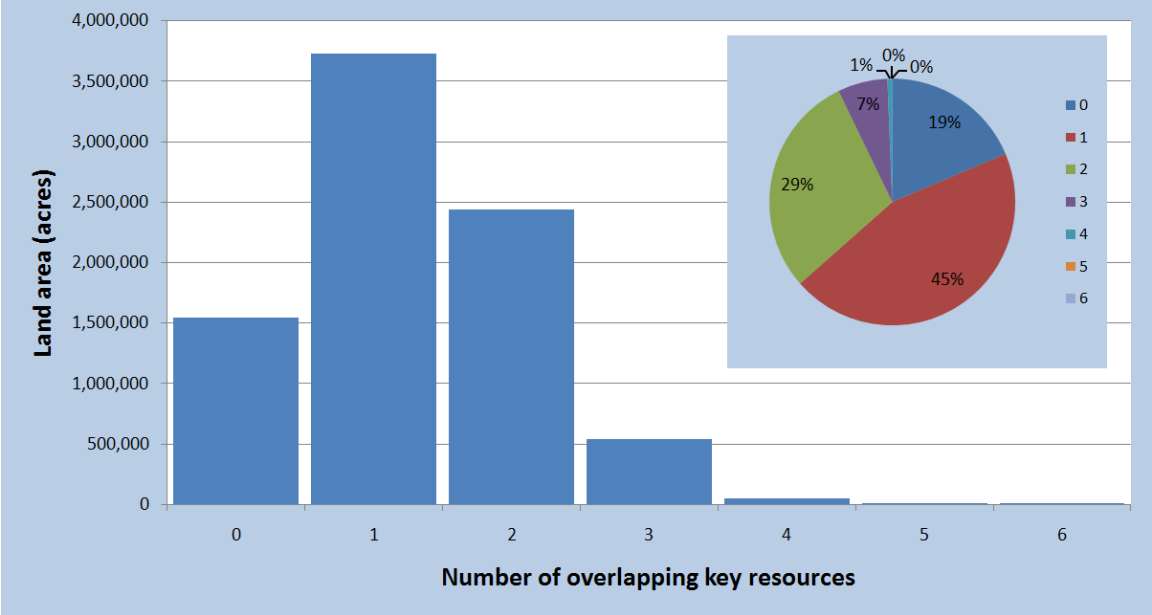

Figure 18. Number of overlapping key resources across the BDNF analysis area by number of acres (main chart) and as a percentage of the total land area (inset).

No key resources are present on approximately 1.5 million acres (19 percent) of the analysis area. A single key resource is present on 45 percent of the analysis area (3.7 million acres). Four or more overlapping resources occur together on just 53,000 acres, less than 0.65 percent of the analysis area.

The wildfire threat calculations described above were performed for each pixel in the analysis area and summarized by resource and BDNF landscape. Overall, residential structures are the most threatened resource or asset on the Forest (figure 19). There are several reasons for this result. First, the response function for residential structures shows a net loss at all fire intensity levels, whereas the response functions for all other resources show at least a mild benefit or neutral response at the lower intensity levels. There are no possible offsetting positive effects of fire on residential structures. Second, the residential structures tend to occur in the valley-bottom grasslands that are conducive to rapid fire spread, and therefore moderate to high burn probabilities and mean fire intensity. Lastly, residential structures are one of the three top-rated resources or assets on the BDNF. However, we made no attempt to identify whether the threat to residential structures in the analysis area is in any way connected to BDNF lands. In some cases the residential structures are located quite a distance from the Forest boundary and are only moderately influenced by fuel conditions on the Forest.

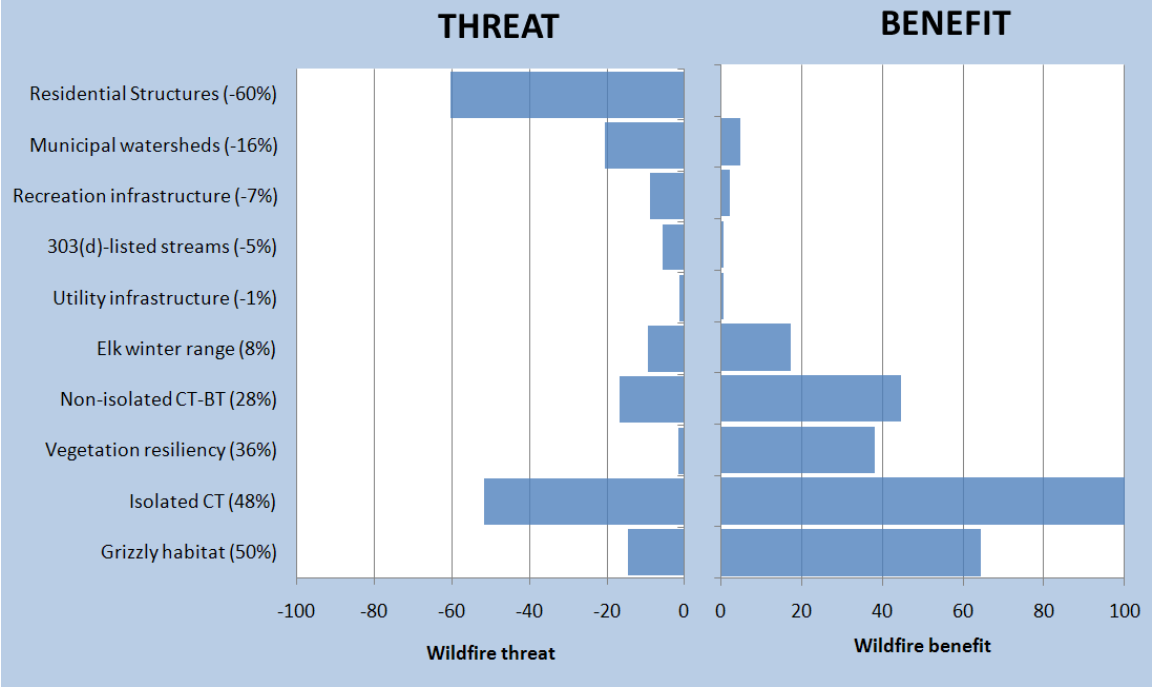

Figure 19. Wildfire threat and benefit to key resources on the BDNF. Threat and benefit values are scaled to the maximum, which in this case is the benefit to isolated cutthroat trout populations.

The second-most threatened resource on the Forest, representing just one-quarter the amount of threat to residential structures, are the municipal watersheds. Municipal watersheds experience a small benefit or neutral response from burning at low intensities but suffer damage when burned at higher intensities. On balance, across the whole Forest, threat outweighs the benefit to municipal watersheds. Unlike residential structures, much of the municipal watershed resource occurs on or very near BDNF land.

Recreation Infrastructure is the third most threatened resource on the forest, but that threat is still less than half of that of the municipal watersheds. However, recreation infrastructure occurs entirely on BDNF land and represents a direct interest to the Forest.

These results suggest that management activities that mitigate the wildfire threat to residential structures, municipal watersheds and recreation infrastructure are likely to produce significant benefits.

On the other side of the coin, half of the key resources are expected to experience a net benefit from wildfire, even though there may be an offsetting threat. Vegetation resiliency exhibits very little threat and almost total benefit from wildfire, making areas where these vegetation types occur good candidates for the planned (prescribed fire) and unplanned use of fire.

Wildfire threat varies among the 12 BDNF landscapes, but certain patterns remain consistent from one landscape to another. Table 3 below lists the rank by overall threat of the five most-threatened resources.

Table 3. Rank of key resources Rank of HVRAs by net wildfire threat for the Forest as a whole and for each landscape.

	Residential Structures	municipal watersheds	Recreation infrastructure	303(d)-listed streams	Utility Infrastructure
Forest-wide	1	2	3	4	5
Boulder River	1	2	4	3	5
Clark Fork - Flints	1	2	3	4	5
Pioneer	1	2	4	3	5
Upper Clark Fork	1	+	+	3	2
Tobacco Roots	1	2	4	3	5
Upper Rock Creek	1	--	3	2	4
Madison	1	--	3	4	--
Gravelly	1	--	3	2	5
Elkhorn	1	--	4	2	3
Big Hole	1	3	4	2	5
Lima - Tendoy	1	--	4	2	3
Jefferson River	1	2	5	3	4
	-- indicates HVRA not present				
	+ indicates positive net response				

Forest wide, residential structures are the most wildfire-threatened resource on the Beaverhead-Deerlodge National Forest, followed by municipal watersheds, recreation infrastructure, 303(d)-listed streams, and utility infrastructure. The remaining HVRAs exhibit a neutral or positive net response to wildfire. Across all BDNF landscapes, residential structures are consistently the most threatened asset. In the landscapes where they exist, municipal watersheds are generally ranked the second or third most threatened HVRA. In the Upper Clark Fork landscape municipal watersheds experience a slightly positive net response. Recreation infrastructure is generally ranked third or fourth most threatened across the BDNF landscapes, while 303(d)-listed streams are ranked between second and fourth. Utility infrastructure is the least threatened of the HVRAs that still experiences a forest-wide negative net response. The remaining HVRAs experience a positive net response to wildfire.

Figure 20 illustrates the variability of cumulative threat and benefit among the landscapes. Because the chart shows cumulative wildfire response, a larger landscape like the Gravelly can exhibit more threat and/or benefit. A smaller landscape like Boulder River has more moderate threat and benefit.

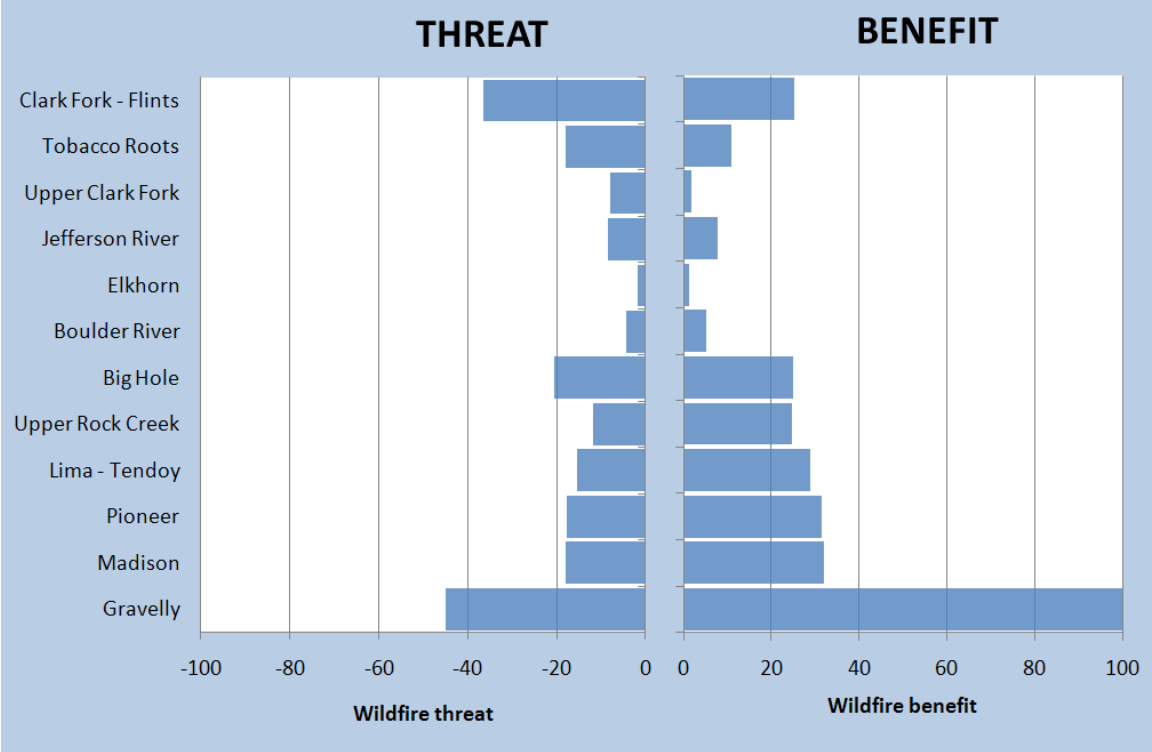

Figure 20. Wildfire threat and benefit by BDNF landscape. Landscapes are listed with the greatest net threat at the top and the most net benefit at the bottom.

The Clark Fork-Flints landscape has the greatest cumulative net threat on the Forest, largely due to the residential structures and recreation infrastructure present there. The Madison and Gravelly landscapes have the greatest net benefit, largely due to the presence of grizzly habitat, whose response function indicates significant positive benefits of wildfire of most fire intensity levels.

It is interesting to note that all landscapes have a balance of positive and negative expected responses to wildfire. The balances shifts toward beneficial responses in some landscapes and toward adverse responses in others, but in all landscapes both positive and negative effects are present.

End-of-outbreak landscape condition

The difference in fuel condition between the 2009 landscape condition and end-of-outbreak condition is subtle (see maps above). The hypothetical end-of-outbreak extent and intensity is expected to be achieved gradually, with each affected stand proceeding through three phases, each with a different effect on fuel, fire behavior and suppression difficulty. During the red-needle phase of the beetle outbreak, no changes in fuel characteristics have yet taken place except a reduction in moisture content of both the red needles and green needles on attacked trees. This lower foliar moisture content can result in both a higher likelihood of torching and crowning; and greater crown fire spread rate and intensity than in the pre-outbreak condition. The red-needle phase is short-lived. The red needles persist on a given tree for just 1 or 2 years, but red-needled trees may be present at a given spot for a longer period of time if trees are attacked over a period of years. The increased hazard of the red-needle phase cannot be mitigated during the short time of its existence.

In the gray phase of the beetle outbreak, red needles have fallen from the trees but the dead trees are still standing. The effect of gray-phase on fuel and fire behavior depends on the relative canopy loss. Very low canopy loss (less than 10 percent) does not significantly change surface or canopy fuel characteristics, so fire behavior is similar to the pre-outbreak condition. Suppression difficulty may be slightly increased over the pre-outbreak condition due to snagfall hazard. Sloughing bark on dead trees may contribute to spotting.

Changes in surface fuel, canopy fuel and suppression difficulty become significant as canopy loss increases, leading to increased surface fuel load as the foliage, fine twigs and small branches fall to the surface (Klutsch et al. 2009). In some vegetation types, grass and shrub load may increase due to the greater availability of sunlight and water (Page and Jenkins 2007). Reduced canopy cover after the outbreak allows more wind and sunlight to reach the surface, resulting in drier (Faiella and Bailey 2007) and windier (Albini and Baughman 1979) conditions at the surface. These changes can significantly increase the surface fire spread rate and intensity over the pre-outbreak condition.

Canopy base height may not increase after the outbreak because the trees remaining after the outbreak are smaller and shade-tolerant understory species that usually determine canopy base height. Since canopy base height remains constant but surface fire intensity increases, milder conditions are required to initiate a crown fire in the post-outbreak condition, corresponding to a decrease in the Torching Index (Scott and Reinhardt 2001). Canopy bulk density declines in proportion to the relative canopy loss (Scott and Reinhardt 2007, Reeves et al. 2009), requiring more extreme conditions to sustain an active crown fire than before the epidemic (an increase in the Crowning Index). Post-outbreak stands are therefore quite prone to passive crowning and are less likely to experience both surface fire and active crown fire than during the pre-outbreak condition (Simard et al. 2010). Passive crown fires exhibit a wide range of behavior, from relatively benign behavior similar to that of a surface fire, where individual or small groups of trees are torching, to extreme behavior similar to an active crown fire. Overall, post-outbreak stands are expected to burn with lower spread rates and fireline intensities than they would have in the pre-outbreak condition, but are still capable of producing extreme fire behavior.

Suppression difficulty increases significantly in the post-outbreak condition, largely due to a significant snagfall hazard to firefighters—it may not be safe for hand crews to operate in heavily affected areas for decades. If fire occurs after the beetle-killed trees fall to the ground, smoke production may increase and soil may be heated to higher temperatures and deeper into the soil, due to consumption of this newly available coarse woody fuel. Construction of fireline is also more difficult for hand crews. Furthermore, as observed on recent wildfires in Canada, sloughing bark from the beetle-killed trees may become effective firebrands capable of starting spot fires downwind.

To quantify this progression toward the hypothetical end-of-outbreak conditions, a second FSIM run was created and the wildfire threat and benefit calculations repeated. Figure 21 below shows the comparison between the wildfire threat and benefit for the 2009 landscape condition (dark blue bars) and for the hypothetical end-of-outbreak condition (light blue bars).

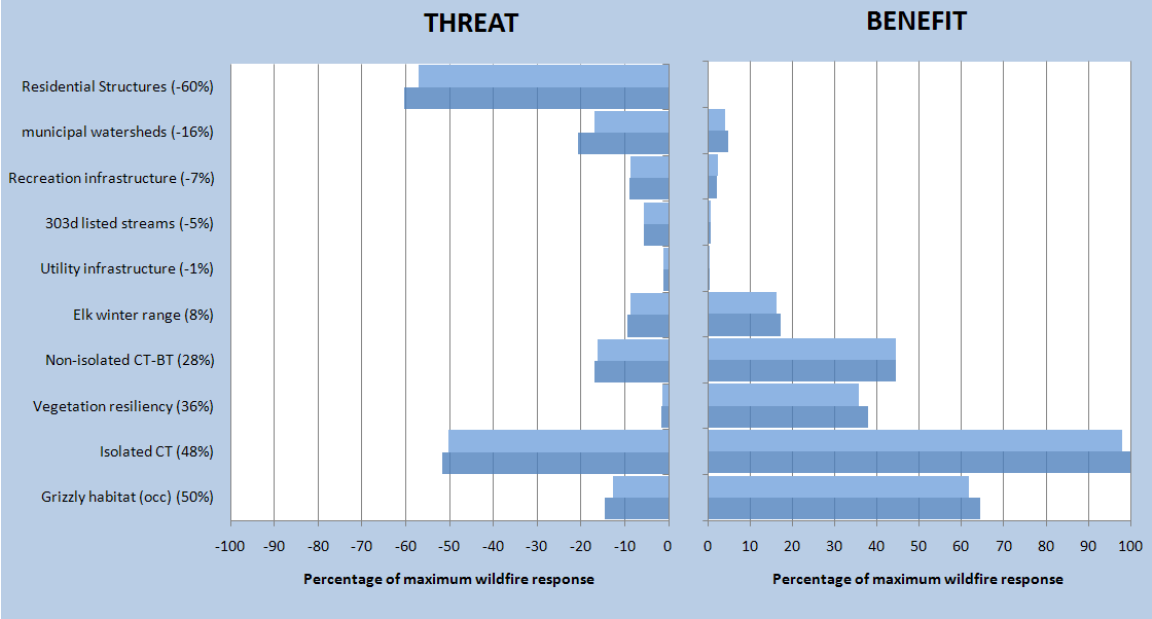

Figure 21. Wildfire threat and benefit for the end-of-outbreak landscape condition (light blue bars) compared to the 2009 landscape condition (dark blue bars).

In general, both threat and benefit are smaller for the hypothetical end-of-outbreak condition, but the relative order of key resources remains identical. The contraction of both threat and benefit is due to slightly lower burn probabilities for the end-of-outbreak condition due to a decreased prevalence of active crown fire and high-grade passive crown fire. The decrease in that crown fire activity is a direct result of the increased extent and intensity of the beetle infestation, which tended to reduce canopy bulk density over the 2009 condition.

Because this hypothetical end-of-outbreak landscape condition was so difficult to simulate, we prefer to rely on the more solid modeling foundation of the 2009 landscape condition and will not present further results on the end-of-outbreak condition simulations.

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Appendix A – Local Fuel Calibration Report

Overview

A local fuels calibration workshop was held in Butte, MT in January 2010 to critique and edit LANDFIRE geospatial fuels data for use in the Rapid Assessment of the Beaverhead-Deerlodge National Forest (BDNF). We refer to this workshop as a "local" calibration to differentiate it from the fire behavior fuel model calibration workshops held by the LANDFIRE program (LANDFIRE 2010a). The purpose of the local calibration workshop was three-fold. First, it provided an opportunity for local land managers to evaluate and make adjustments to the assumptions and fuel mapping rules developed for the *LANDFIRE National*[1] fuels data which are generalized to map zones that encompass a larger area (tens of millions of acres) than the Rapid Assessment (figure A1). Second, it provided an opportunity to update the fuels data to reflect changes resulting from recent wildfire and insect disturbances ahead of the *LANDFIRE Refresh* schedule. Lastly, the local calibration workshop provided a sense of ownership in the resulting geospatial data to the workshop participants. The final products are seamless, locally calibrated surface and canopy fuel data, based on LANDFIREs' core mapping of existing vegetation type, existing vegetation cover, existing vegetation height, and biophysical setting.

This report provides an overview of the local calibration process and the changes made to the original *LANDFIRE National* data for this assessment

Pre-Workshop Data Acquisition and Preparation

The analysis area of the BDNF Rapid Assessment included portions of four LANDFIRE mapping zones. The calibration extent is shown in figure A1.

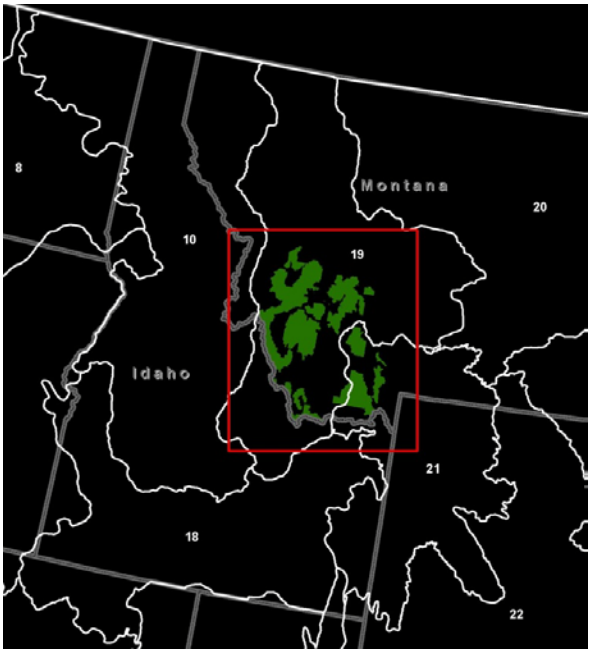

Figure A1. LANDFIRE mapping zones (white outlines), calibration extent (red box), and Beaverhead-Deerlodge NF (green polygons).

[1] See http://www.landfire.gov/version_comparison.php for an overview of LANDFIRE geospatial data versions.

We used the LANDFIRE Data Access Tool (LFDAT) (LANDFIRE 2010b) to download the existing vegetation type (EVT), existing vegetation cover (EVC), existing vegetation height (EVH), biophysical setting (BpS), elevation, slope, aspect, and original fire behavior fuel model (FBFM) geospatial layers for the calibration extent. These layers were kept in the LANDFIRE (USGS) Albers equal area conic projected coordinate system for the calibration.

Two adjustments to the base geospatial data were made prior to the workshop. First, LANDFIRE's published forest canopy cover layers are known to overestimate this factor. For this reason, we reduced canopy cover for tree life forms (forest canopy cover) in the EVC layer using the recommended procedure posted on the LANDFIRE website (LANDFIRE 2010c) and then reassigned the reduced values back to the original classes (table 1). No adjustment was made to herbaceous or shrub canopy cover. Second, LANDFIRE applies additional rock and water calibration to its published fuel layers but not to the base EVT, EVC, EVH, or BPS layers. We used the original FBFM layer to update for the additional rock and water. Note: the regional fire ecologist provided a geospatial layer of additional, region specific, rock and water updates to the base LANDFIRE data. We applied these updates to the final fuel layers after the calibration.

Table A1. Forest canopy cover adjustment.

Original Canopy Cover Range	Adjusted Canopy Cover Range
>=10 and <20%	No Change
>=20 and <30%	No Change
>=30 and <40%	No Change
>=40 and <50%	>=30 and <40%
>=50 and <60%	>=30 and <40%
>=60 and <70%	>=40 and <50%
>=70 and <80%	>=50 and <60%
>=80 and <90%	>=60 and <70%
>=90%	>=60 and <70%

The BDNF calibration extent includes portions of four LANDFIRE mapping zones: 10, 18, 19, and 21, with the majority of the BDNF land in zone 19 (figure A1). Inconsistencies in fuel mapping rules between map zones are quite common. To address these inconsistencies prior to the workshop, we combined rules from multiple map zones in a beta version of the Total Fuel Change Tool (ToFuΔ)[2]. ToFuΔ is a custom ArcGIS toolbar for critiquing and editing LANDFIRE fuels data that incorporates a database containing the fuel mapping rules developed at the *LANDFIRE national* fuel model calibration workshops for each map zone. Fuel mapping rules are grouped by EVT. We first copied the rules from the dominant map zone (zone 19) to a new ToFuΔ management unit. Next, rules for EVTs absent in zone 19 but present in one or more of the other zones were copied giving preference to zone 21 because it covered the remainder of the BDNF land. Finally, each forested EVT fuel model rule was adjusted to reconcile any differences in canopy cover thresholds due to the reduction made to forest canopy cover shown in table 1. Adjustments were made to match the original distribution of fuel as closely as possible.

Geospatial data on recent (1999 – 2009) natural disturbances were acquired from the Monitoring Trends in Burn Severity (MTBS) program (MTBS 2010), BDNF staff, and Region 1 Geospatial

[2] A release version of the ToFuΔ toolbar, user's guide, tutorial, and help utility are available from the NIFTT Downloads page at www.fire.org.

Services Group. Burn severity data was available from MTBS through 2007. Data of burn severity for 2008 and 2009 wildfires was provided by the BDNF staff. The Region 1 Geospatial Services Group provided data of relative overstory canopy loss from 2000 – 2009 (Ahl et al. 2010). This data was used to estimate canopy reduction due to beetle infestation after masking out the wildfire disturbance.

Data Critique and Modification

Surface and canopy fuel mapping

We used a beta version of ToFuΔ to critique the LANDFIRE surface and canopy fuel data for the calibration extent. Fuel mapping rules are based on combinations of EVT, EVC, EVH, and BpS. ToFuΔ was used to iteratively make adjustments to the fuel mapping rules and review the resulting spatial distribution of surface fire behavior fuel model (FBFM), canopy base height (CBH), and canopy bulk density (CBD).

The FBFM mapping rules for each EVT were evaluated by the workshop participants and modifications were made where appropriate to better reflect the expected surface fire behavior. Note: some of the rules were modified post-workshop based on field review and BDNF staff input.

LANDFIRE National CBH layers are known to overestimate this factor. CBH was mapped at the workshop using a new method developed by the LANDFIRE program which is available in ToFuΔ. This method will be used in future LANDFIRE products.

CBD was mapped at the workshop using a general linear model produced by LANDFIRE (Reeves et al. 2009). The GLM is also not used in the current *LANDFIRE National* data, but will be used in future LANDFIRE products. The GLM is essentially a non-linear regression of CBD against forest canopy cover and forest canopy height. The data used to create the GLM came from the LANDFIRE Reference Database (LANDFIRE 2010d).

Wildfire and beetle disturbance

Vegetation and disturbance processes are dynamic and therefore so is the data we use to represent them. Geospatial data are never complete and regular updates are required to keep current. As stated above, geospatial data on burn severity and the distribution and severity of the beetle infestation were compiled to update the circa 2000 *LANDFIRE National* base layers to 2009.

Wildfire updates:

Disturbance data used in ToFuΔ need to follow a specific classification representing disturbance type, severity, and time since disturbance. Table A2 shows the reclassification of MTBS data for use in ToFuΔ. 2008 and 2009 wildfires were assigned a burn severity and time since disturbance by BDNF staff and incorporated into the final burn severity layer and ToFuΔ classification. After reviewing mapping rules for the non-disturbed areas we used ToFuΔ to develop surface and canopy fuel mapping rules for areas burned in wildfires between 1999 and 2009 based on pre-fire FBFM, severity, and time since disturbance. These rules were applied to create an updated post-wildfire geospatial layer of FBFM.

Table A2. Reclassification of MTBS data for use with ToFuΔ.

MTBS Classification	ToFuΔ Classification			
Severity	**Disturbance type**	**Severity**	**Time since disturbance**	**Final code**
(0) NoData	0	0	0	0
(1) Unburned	0	0	0	0
(2) Low	1 (fire)	1 (low)	1 (< 5 yrs.)	111
			2 (≥ 5 yrs.)	112
(3) Moderate	1 (fire)	2 (moderate)	1 (< 5 yrs.)	121
			2 (≥ 5 yrs.)	122
(4) High	1 (fire)	3 (high)	1 (< 5 yrs.)	131
			2 (≥ 5 yrs.)	132
(5) Enhanced regrowth	1 (fire)	1 (low)	1 (< 5 yrs.)	111
			2 (≥ 5 yrs.)	112
(6) Not processed	1 (fire)	1 (low)	1 (< 5 yrs.)	111
			2 (≥ 5 yrs.)	112

To account for the effect of wildfire on canopy fuels we modified EVC and EVH as shown in table 3. Forest canopy layers (forest canopy cover, forest canopy height, CBH, and CBD) were then created using ToFuΔ.

Table 4. Forest canopy adjustments for low, moderate, and high severity wildland fire.

Canopy Attribute	Low Severity	Moderate Severity	High Severity
Forest canopy cover reduction	10%	40%	100%
Forest canopy height reduction	None	None	100%

Beetle updates:

We used the spatial analyst extension to ArcGIS instead of ToFuΔ to update the landscape for the beetle infestation. Four classes of relative overstory canopy loss were mapped by the Region 1 Geospatial Services Group (Ahl et al. 2010). To account for changes to the surface fire behavior fuel model as a result of the beetle infestation, we created an expert-opinion lookup table based on the pre-infestation fuel model and canopy loss class (table 4). Spatial analyst was used to update the post-wildfire surface fire behavior fuel model layer.

Table 5. Surface fire behavior fuel model adjustments for low, moderate, high, and very high canopy loss from beetle infestation.

Existing FM	Low (10-25% loss)	Moderate (25-50% loss)	High (50-75% loss)	V. High (75-100% loss)
TU1	NA	TU2	TU2	TU2
TU2	NA	TU2	TU2	TU5
TU5	NA	TU5	TU5	TU5
TL1	NA	TL3	TL4	TL7
TL3	NA	TL4	TL7	TL5
TL4	NA	TL4	TL7	TL5
TL8	NA	TL8	TL8	TU2

The post-wildfire canopy height and canopy base height were assumed to remain unchanged following the outbreak, the rationale being that canopy height is an average value and has a marginal effect on fire behavior and that the beetles typically do not affect the smaller trees that contribute most to canopy base height. Canopy cover and canopy bulk density were reduced in proportion (Scott and Reinhardt 2007) to the mid-point Region 1 canopy loss values (table 5).

Table 6. Forest canopy reduction for low, moderate, high, and very high canopy loss from beetle infestation.

Canopy Attribute	Low (10-25% loss)	Moderate (25-50% loss)	High (50-75% loss)	V. High (75-100% loss)
Forest canopy cover and bulk density reduction	17.5%	37.5%	62.5%	87.5%

Landscape File Preparation

Fire behavior modeling systems such as FlamMap (Finney 2006), FARSITE (Finney 1998), and FSIM require a landscape file (LCP) to model fire behavior characteristics. An LCP is comprised of geospatial data of elevation, aspect, slope, fire behavior fuel model, forest canopy height, forest canopy cover, forest canopy base height, and forest canopy bulk density. As a final step, we projected the calibrated fuels and topography layers to the local NAD 1983 UTM Zone 12 North projected coordinate system to minimize the true north - grid north distortion of the LANDFIRE (USGS) Albers equal area conic projected coordinate system (LANDFIRE 2010e). This data can now be used to create a seamless, locally calibrated LCP for use in fire behavior modeling systems anywhere on the Beaverhead-Deerlodge National Forest.

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Appendix B –Simulating end-of-outbreak relative canopy loss

This Appendix describes the use of FIA plots from the Beaverhead-Deerlodge National Forest (544 plots available) to provide estimates of relative canopy cover loss due to mountain pine beetle and summarize by existing vegetation type and size class. This Appendix is an abstract of an internal report prepared by Ann Wolf and Renate Bush of the USFS R1 Regional Office.

Method

FIA data available

There are 2 types of FIA data that will be used for this analysis:

- Periodic/variable-radius plot (periodic data): installed/measured in 1996-1997, 547 total plots. This data was used in the most recent B-D Forest Plan Revision.
- Annual/mapped-plot (annual data): 10% of the plots across the Forest are measured each year. Montana data started collection in 2003. Currently have data from 2003- 2007 available, 292 plots.

To portray current condition, a hybrid FIA dataset will be derived containing:

- all of the annual plots that are available in FSVeg for R1 for the B-D
- any periodic plots where annual plots have not been measured/released to NFS

This will provide a complete set of FIA plots across the B-D for analysis comprised of 252 periodic and 292 annual plots. The hybrid data will be used to show most current information. The beetle infestation started on the B-D in 2005 and continues its progression today. Although some of the annual FIA plots have been measured since infestation started, many of the annual plots and all of the periodic plots do not represent post-beetle condition.

Total # plots	544
Forested plots	450
Forested plots with live trees	448

Using FVS to Model Mortality

The analysis team worked with Carol Randall from Forest Health Protection (FHP) to determine the MPB mortality rates used in FVS. FVS keywords were created to depict future condition given low or high mortality based on Forest Insect and Disease Tally System (FINDIT) assessments on the B-D; observed mortality rates calculated from re-measured intensified grid data from the Helena NF; and expert knowledge.

Determining where to apply mortality

FHP, Brytten Stead and Carol Randall, then created a coverage for the B-D which attributed 5th code HUCs with how long MPB has been within the HUC. They determined that all HUCs had MPB influence for at least 5 years and that after MPB has been in an area for 10-years, the infestation is finished. The Analysis Team worked with FHP to use the FIA plot's inventory date and 5th code HUC time of infestation, to determine when to apply mortality and to what extent

Using FVS to simulate beetle kill on FIA plots

We used the Forest Vegetation Simulator to simulate beetle mortality using keyword files developed in conjunction with Chad Keyser (Appendix A). We modeled the projected condition of the plots after MPB outbreaks. We chose to apply mortality in 5 year steps. This was because MPB kills trees for about 10 years , according to FHP folks. The MPB-simulated mortality is added to background mortality in FVS.

For documentation on these keyword files see Assessing Potential Mortality from Mountain Pine Beetle in Lodgepole Pine, Ponderosa Pine, and Whitebark/Limber Pine using the Forest Vegetation Simulator (FVS) (http://fsweb.r1.fs.fed.us/forest/inv/mpb/mortalitylogic.docx)

Assessing Canopy Cover Loss

We analyzed the FVS simulation output for each of the 448 plots forested with live trees. Total canopy cover was computed by equations within FVS at both the time of inventory and at the end of the simulation (year 2020). We computed canopy cover loss by subtracting canopy cover in 2020 from canopy cover at the time of inventory. If canopy cover in 2020 was greater than canopy cover at time of inventory (due to growth in the model), we set canopy cover loss equal to zero.

Because the number of years of the simulation varied between plots (time of inventory ranged from 1996 to 2007), we computed canopy cover loss on an annual basis by dividing total canopy cover loss over the course of the entire simulation by the number of years the plot was being simulated (2010 – year of inventory). We then projected canopy cover loss over a 20 year period.

We classified each plot at time of inventory using the R1 existing vegetation classification system (Barber et al.) and used dominance plurality 60% and size class NTG to group the plots for further analysis.

After analyzing the data we noted that canopy cover loss due to the beetle was being offset by the natural growth processes going on in FVS. In essence we were only seeing ‘net’ canopy cover loss, not the total or gross that we wanted to get at. To account for this, we ran the plots through FVS with no beetle mortality keywords to get a sense of how the canopy cover changes due to 'natural' processes like growth and mortality. We saw that, for some dominance types of interest, canopy cover increased substantially over a 20-year period (eg. PICO plots increase their canopy cover % by an average of 9% over a 20 year period). This 'growth' going on in FVS is off-setting canopy cover losses that occur due to the beetle.

Combining the no-beetle output with the beetle output allowed us to compute ‘gross’ canopy cover loss due to the beetle.

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