Analysis of Vegetation Mortality and Prior Landscape Condition, 2002 Biscuit Fire Complex

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Introduction

The Biscuit Fire Complex burned nearly 500,000 acres in southwest Oregon and part of northern California between July 13 and September 6, 2002. Since it was the largest fire this year and in Oregon's recent history, the conditions leading to this fire and the effects of the fire have received much attention from scientists and politicians. Pacific Biodiversity Institute conducted this analysis in order to come to a better understanding of the influence of management and landscape condition on the how the fire affected the landscape.

This study analyzes the vegetation mortality that resulted from the fire and landscape condition factors that may have influenced vegetation mortality and fire severity. A prior study by the same authors (Harma and Morrison 2002a) assesses the general characteristics of the fire area in relationship to total burn area and fire progression.

Our analysis consists of four main components: A comparison of two methods of assessing fire effects; fire effects as related to logging history; fire effects as related to previous burns; and fire effects as related to management designation. A subset of the analysis of logging history was an analysis of fire effects in land that was salvage logged after the 1987 Silver Fire. The vegetation mortality data used for the analysis was based on our interpretation of pre-fire and post-fire satellite imagery. We compared the results of this vegetation mortality map to a burn severity map created by the Forest Service.

Methods

Mapping of vegetation mortality occurring after the Biscuit Fire Complex

The first step in analyzing how the Biscuit Fire Complex affected the landscape under different management designations and conditions is to determine how the fire affected vegetation. We used pre-fire and post-fire satellite imagery to create a map of vegetation mortality in the fire area.

We obtained Enhanced Landsat Thematic Mapper 7 satellite imagery taken before the fire (August 27, 2001) from the Remote Sensing Applications Center, and taken after the fire (August 30, 2002) from the Siskiyou National Forest. We used Image Analysis software from ERDAS and Environmental Systems Research Institute (ESRI) to derive burn severity indexes using these satellite images. First, we determined the vegetation condition before and after the fire using the infrared reflectance bands 4 and 7, which have been determined to exhibit the greatest reflectance change in response to fire (Key and Benson, 1999). We used a modification of the normalized difference vegetation index (NDVI) as calculated by [(TM4-TM7)/(TM4+TM7)] (Key and Benson, 1999). Since the before and after satellite images were taken at the same time of year, the state of vegetation growth is similar between both years.

We derived the difference between the two images by subtracting the post fire vegetative index from the pre-fire index. The result indicates how much vegetation was lost in the fire. The image difference information is on a continuous scale, and in order to break out these numbers into "high" "moderate" "low" and "unburned" we examined the original satellite images and the derived vegetation indexes. In splitting the resulting values into "high" "moderate" and "low" classes, we considered loss of vegetation in all vegetation types, not just forested vegetation types. This method was designed to come to the closest approximation of actual mortality of vegetation including grasses, shrubs and trees.

A small portion of the fire area (on the northern edge) was not included in the vegetation mortality analysis because the available satellite imagery did not cover that area and other sources of information were not available. All analyses with logged areas and management designations looked only at those management types within the portion of the fire for which vegetation mortality is mapped.

PBI's Vegetation Mortality Classes:

- High Mortality: Most to all aboveground vegetation burned by fire. Includes both forested and non-forested vegetation types.
- Moderate Mortality: More than half of the aboveground vegetation is burned by fire.
- Low Mortality: Half or less of the aboveground vegetation is burned or browned. Significant portions of green vegetation still present.
- Very Low to no Mortality: Very little burned or browned vegetation. Most vegetation is still green.

It is important to note that our assessment was of immediate vegetation mortality. Many herbs, grasses and shrubs may resprout after a fire burns above ground vegetation. Some burned trees may also survive, even when they appear severely scorched. Some trees may die several years after the fire due to fire damage and loss of hardiness to withstand insects and diseases.

A comparison of PBI vegetation mortality mapping to Forest Service BAER burn severity mapping

The Burned Area Emergency Rehabilitation (BAER) team for the Siskiyou National Forest developed a fire severity map using similar methods. The Burned Area Emergency Rehabilitation (BAER) teams' goal is to identify areas in need of immediate restoration. They define fire severity in terms of "changes in soil hydrologic function (infiltration, erosion hazard) and ecosystem impacts (revegetation potential, changes in vegetation community composition)" (Parsons and Orlemann 2002). Their fire severity determinations are not meant to be a direct reflection of vegetation condition. Nonetheless, their fire severity information is also based primarily on satellite imagery obtained before the fire (August 27, 2001) and after (August 30, 2002) the fire. We compared our vegetation mortality map to their burn severity map and found some major discrepancies, which will be described in the ***Results*** section of this paper.

Analysis of vegetation mortality in logged and unlogged areas

Once we completed the vegetation mortality map, we began our analysis of the relationship between fire effects and land management. The first component in this analysis was to determine if vegetation mortality in the Biscuit Fire Complex differed between logged and unlogged areas.

Logging data was obtained from the Siskiyou National Forest, and updated and enhanced by PBI based on interpretation of Landsat TM7 satellite imagery from August 27, 2000 and August 30, 2001 as well as digital aerial photographs from 1994 and 2000.

We verified and corrected the USFS logging history layer using a sequence of MSS satellite imagery from 1972, 1973, 1974, 1984 and 1986, as well as Landsat TM satellite imagery from 1989 and 1994. Information on date and type of cut was retained from the original Forest Service data, and estimated date of cut was added to the newly digitized cuts. However, for the purposes of this analysis, all areas were considered as either logged or not logged. Vegetation mortality was determined using PBI's satellite image differencing method (described in methods above).

Logging units affected by the Biscuit Fire Complex are concentrated in three parts of the fire area. Due to the differences in topography, vegetation, and time-burned, we decided to split the logging units into three different regions for analysis.

Area A is along the western flank of the fire. This region is dominated by Douglas-fir forests (GAP analysis mapping) and has gentle slopes (majority between 0% and 27%). The area burned between August 11 and August 30, 2002. Approximately 24% of this area has been logged.

Area B is in the northern portion of the fire. This region is dominated by Douglas-fir and pine forests (GAP analysis vegetation mapping) and is at a higher elevation with steep slopes (majority between 25% and 55%). The southern part of this area is near the ignition point of the Florence Fire and contains land burned through August 18. Approximately 12% of this area has been logged.

Area C is on the eastern edge of the fire. This region is characterized by Douglas-fir and pine, and has moderately steep slopes (25% to 45%), and burned between July 29 and August 4. Approximately 15% of this area has been logged.

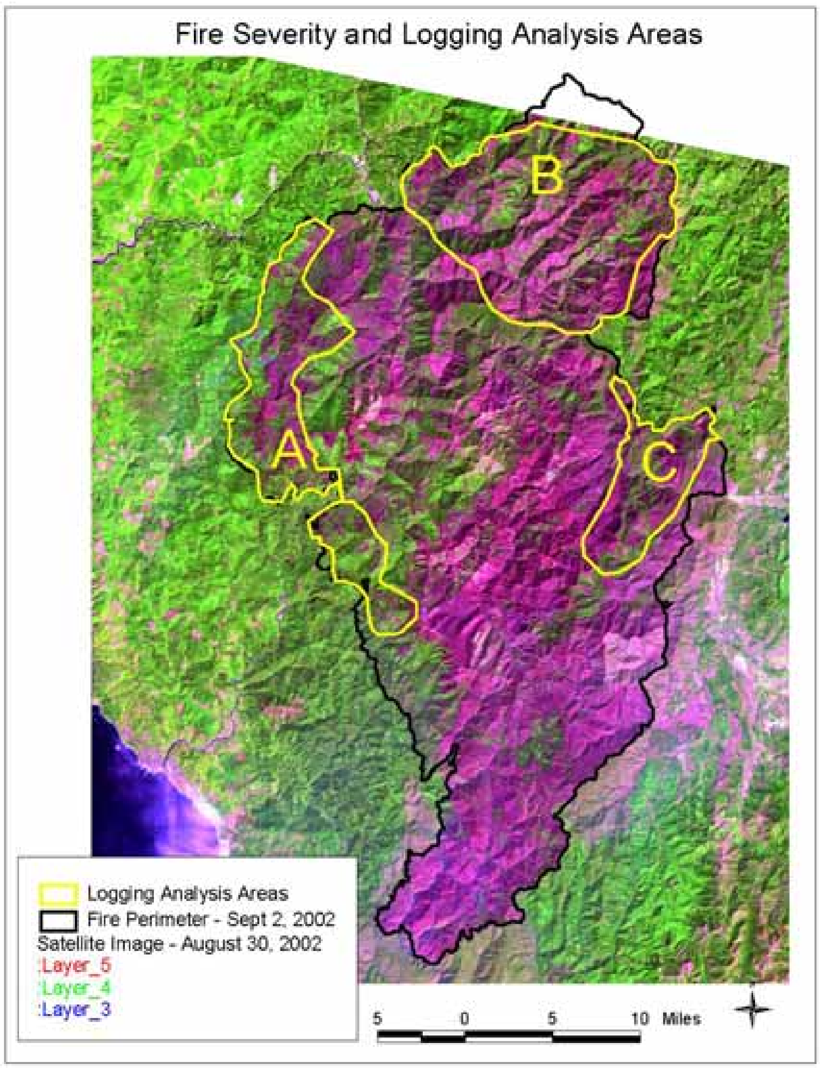

Figure 1: Vegetation Mortality and Logging Analysis Areas

Next, we analyzed the logged and unlogged portion of each analysis area. We used the vegetation mortality data to calculate the proportion of each class (high, moderate, low vegetation mortality and unburned) in the logged and unlogged areas.

Vegetation mortality in areas of previous fires

An initial review of the vegetation mortality data indicated that the fire effects differed greatly in areas burned by previous fires. To test this hypothesis, we intersected a data layer of locations of previous fires with our vegetation mortality data layer. Fire history data was obtained from the Siskiyou National Forest. We broke this data out into fires that burned within the Biscuit Fire Complex perimeter in the last decade (1990 to present) and those that burned in the 1980s.

Vegetation mortality in areas salvage-logged after the Silver Fire

The 1987 Silver Fire was the major fire in the 1980s, burning 96,310 acres. The 2002 Biscuit Fire Complex burned throughout the entire area previously burned in the Silver Fire. Several salvage logging operations and other harvest activities were completed in the fire area in 1987 through 1990. We examined vegetation mortality both within the Silver Fire perimeter and within the areas that were salvage-logged subsequent to the fire.

Vegetation mortality and management designation

The area of the Siskiyou National Forest where the Biscuit Fire Complex burned is managed under a variety of different management designations under both the Northwest Forest Plan and Siskiyou National Forest's forest plans. The Northwest Forest Plan management designations examined include: Late Successional Reserves, Key Watersheds and Matrix. Vegetation mortality in Inventoried Roadless Areas was also examined. In order to assess how the fire burned in the land managed under the different plans, we intersected data on each management type with our vegetation mortality map.

Results and Discussion

Pacific Biodiversity Institute's vegetation mortality mapping (Figure 2) shows a mixture of high, moderate, low and unburned land occurring throughout the fire area.

Results of comparison of our vegetation mortality map with the BAER burn severity map

One difference between the Forest Service BAER mapping and PBI's mapping is that the BAER maps tended to lump areas of high and low severity together. For example, in the BAER map, many areas mapped as low severity had large pockets of high vegetation mortality within them. PBI's mapping looked at vegetation mortality at a finer scale, and created a map that is more spatially accurate (Figure 3).

Another difference between the Forest Service BAER mapping and PBI's mapping is related to how the BAER criteria for the severity class was determined. The BAER fire severity mapping appears to have assumed that early successional vegetation (grass, herbs, shrubs and very young trees) burned at a low severity. In the explanation of the breakout of the different classes, the BAER report states that in sparsely vegetated areas the fire "probably spread rapidly but residence time was short due to paucity of ground fuels".

Given the inaccessibility of much of the fire area, the precise condition of the pre-fire ground fuels for most areas within the fire perimeter cannot be ascertained by either the Forest Service personnel or the authors of this study. These sparsely vegetated or early successional vegetation areas may have burned intensely due to large amounts of ground fuels. We believe that it is incorrect to assume that they burned at a low severity, as was done in the Forest Service BAER study. Often shrub fields and young conifer plantations burn intensely with high heat input into the soil surface layers. Without a detailed field check in many areas of the fire, a comparison of pre- and post-fire vegetation condition is the best indication of vegetation mortality. PBI's mapping concentrates on what is readily visible from satellite imagery, i.e. a comparison of the amount of live vegetation before and after the fire. We do not attempt to estimate the long-term recovery potential of the ecosystem, nor try to understand the effects on soil.

A third difference between the Forest Service BAER mapping and PBI's mapping is that the BAER burn severity classes include the same range of vegetation mortality values in each severity class. For example, the vegetative loss value of –55 is included in the low, moderate and high severity class (Figure 4). In PBI's classification, -55 is included in the high class only.

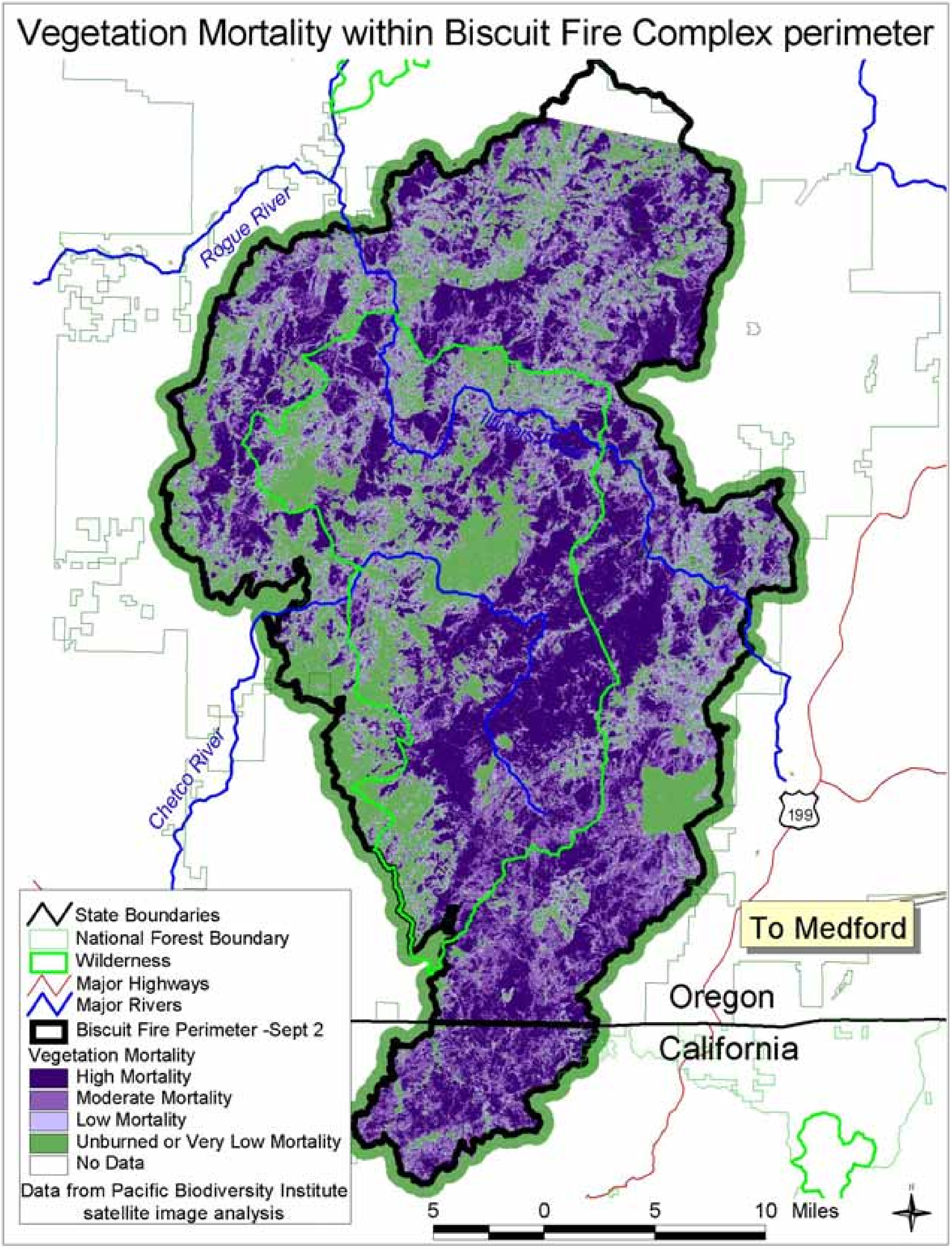

Figure 2: Map of vegetation mortality in the entire Biscuit Fire Complex area using PBI satellite image-differencing methods. The northern tip of the fire area is excluded because the satellite images did not cover that area.

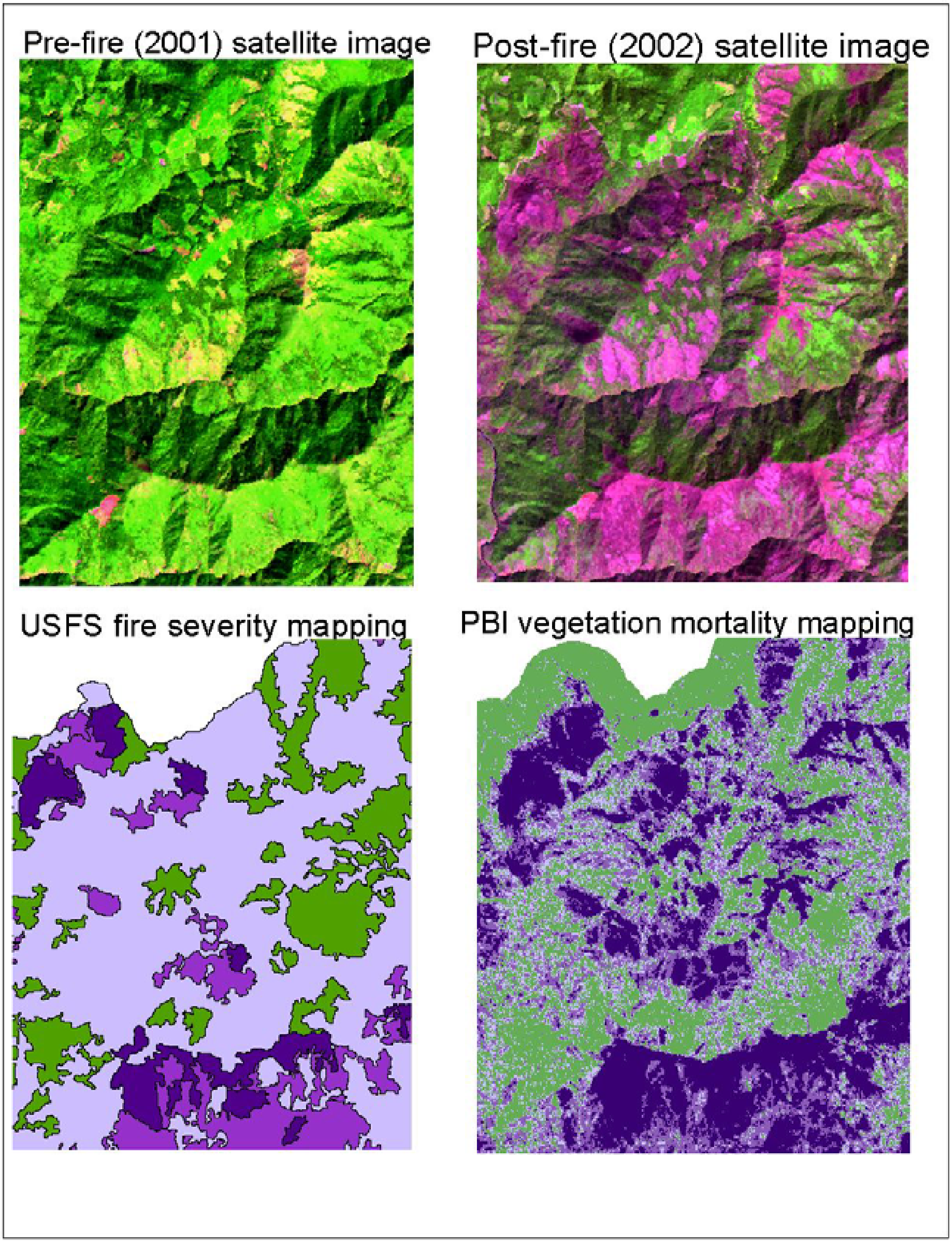

Figure 3: This is the same scene from an area burned by the Biscuit Fire Complex. The top two images are pre- and post-fire satellite images. Note the change from green to purple (burned) in most areas. The lower images show the USFS BAER mapping and PBI's mapping. PBI's mapping shows more spatially accurate and objective information on where burned and lightly burned vegetation is present.

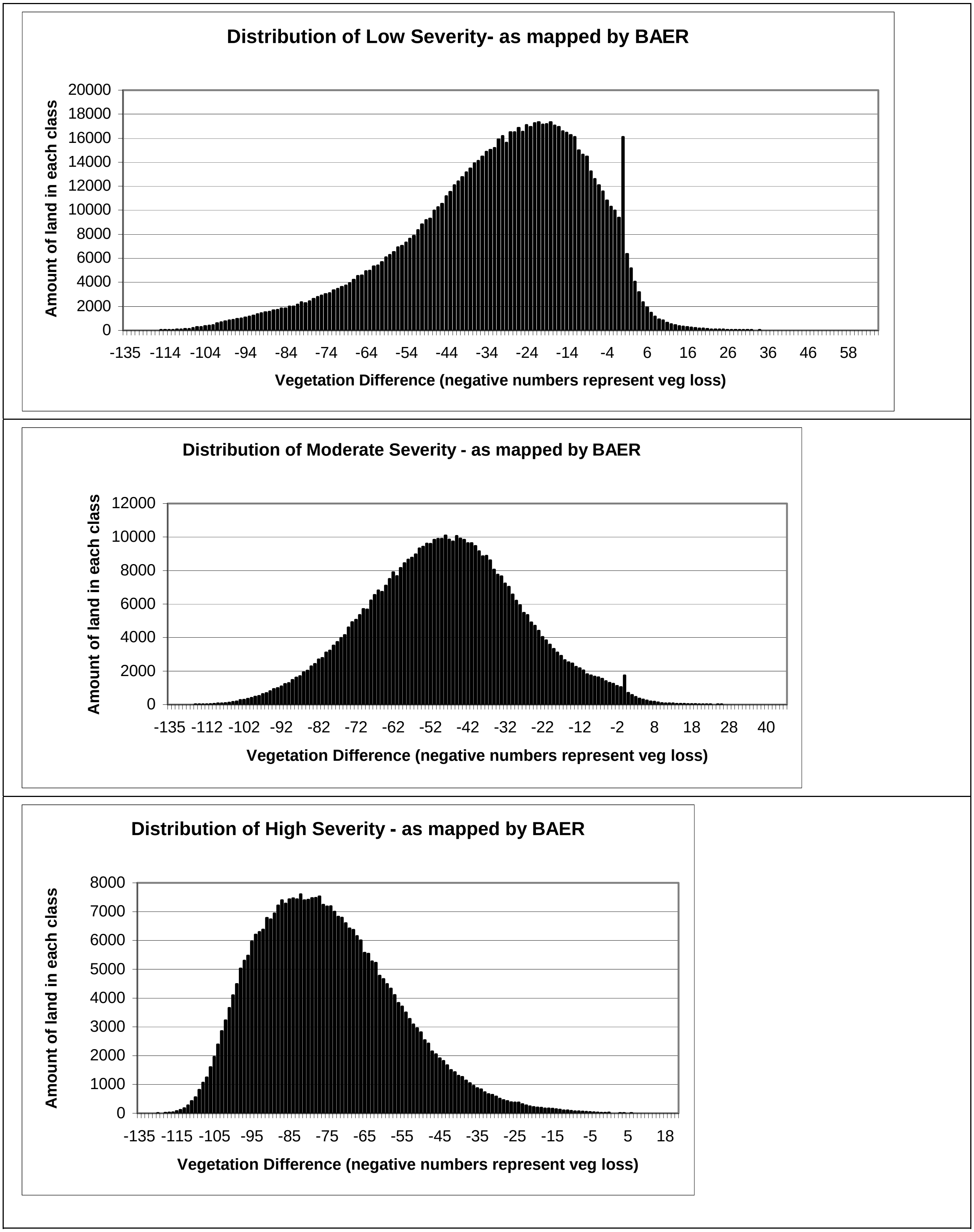

Figure 4: Graphs of distribution of image difference values in the BAER map categories of low, moderate, and high burn severity. The image difference values represent amount of vegetation loss.

Analysis of vegetation mortality in logged and unlogged areas

In the logged portions of **Area A**, a greater proportion of land (11% higher) was burned with high vegetation mortality than in the unlogged areas. In the unlogged area, a greater proportion of land (10% higher) was burned with only very low vegetation mortality or was unburned than on logged land.

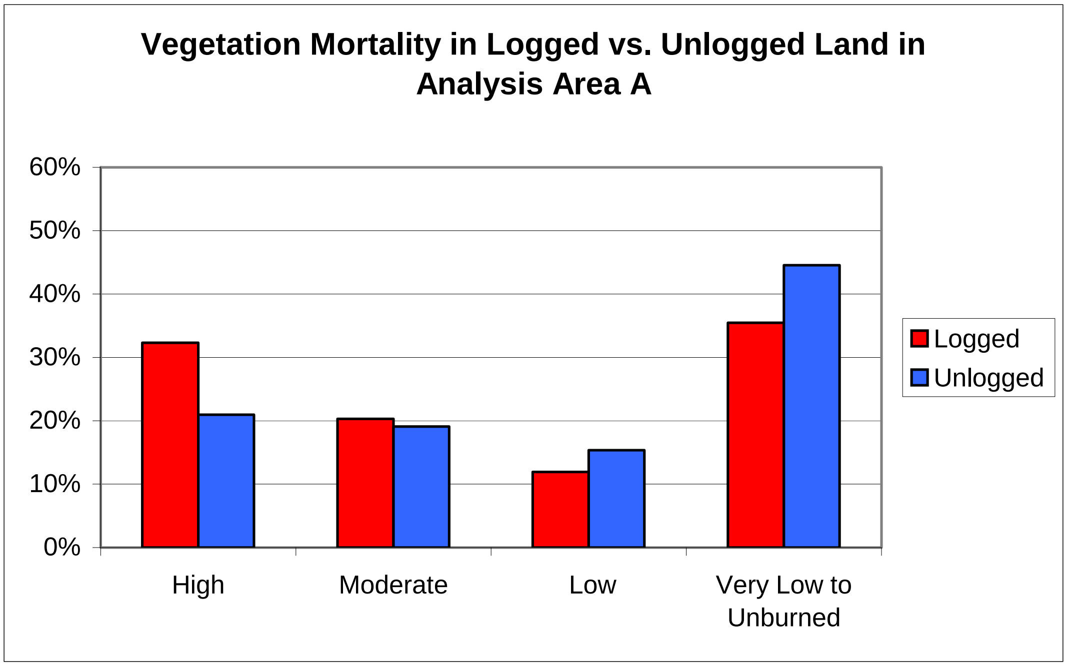

Figure 5: Vegetation mortality in logged and unlogged areas in Area A of the Biscuit Fire Complex

In **Area B**, the logged areas had a much greater proportion (26% higher) of land burned with high vegetation mortality, and the unlogged areas had a greater proportion of low vegetation mortality (9% higher) and of unburned land (14% higher).

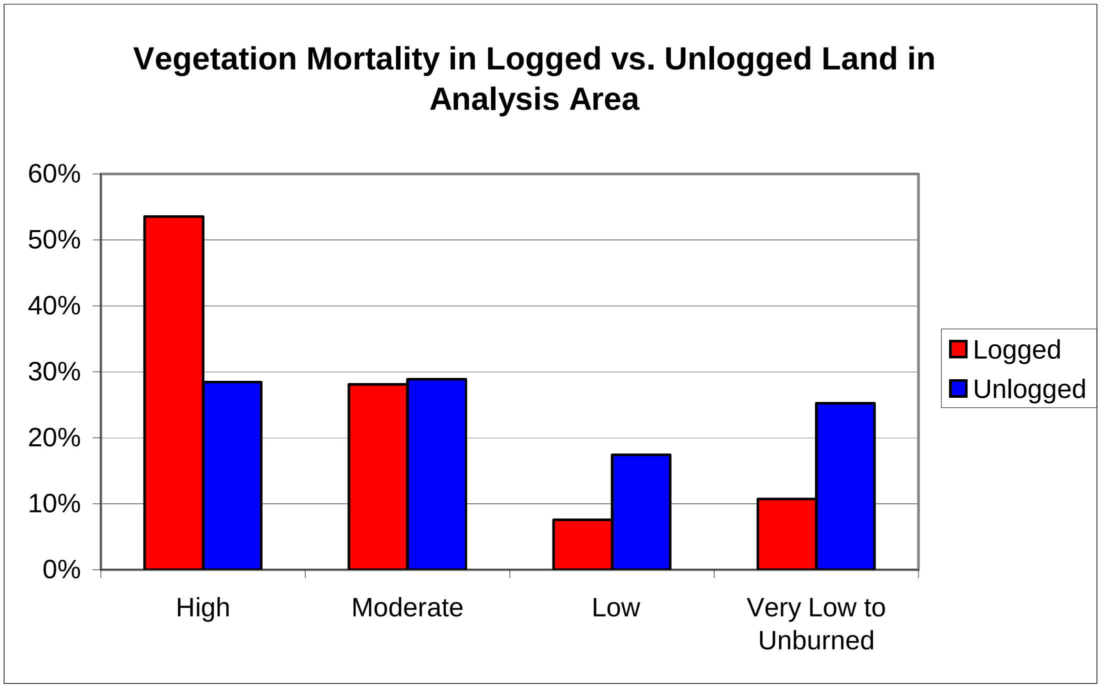

Figure 6: Vegetation mortality in logged and unlogged areas in Area B of the Biscuit Fire Complex

Area C shows a slightly different trend. The proportion of land burned with high vegetation mortality is similar in logged and unlogged lands. The trend seen in Areas A and B is still present to some extent, as there is a greater proportion of land burned with moderate vegetation mortality in logged areas. There is also a greater proportion of unburned land on the unlogged lands.

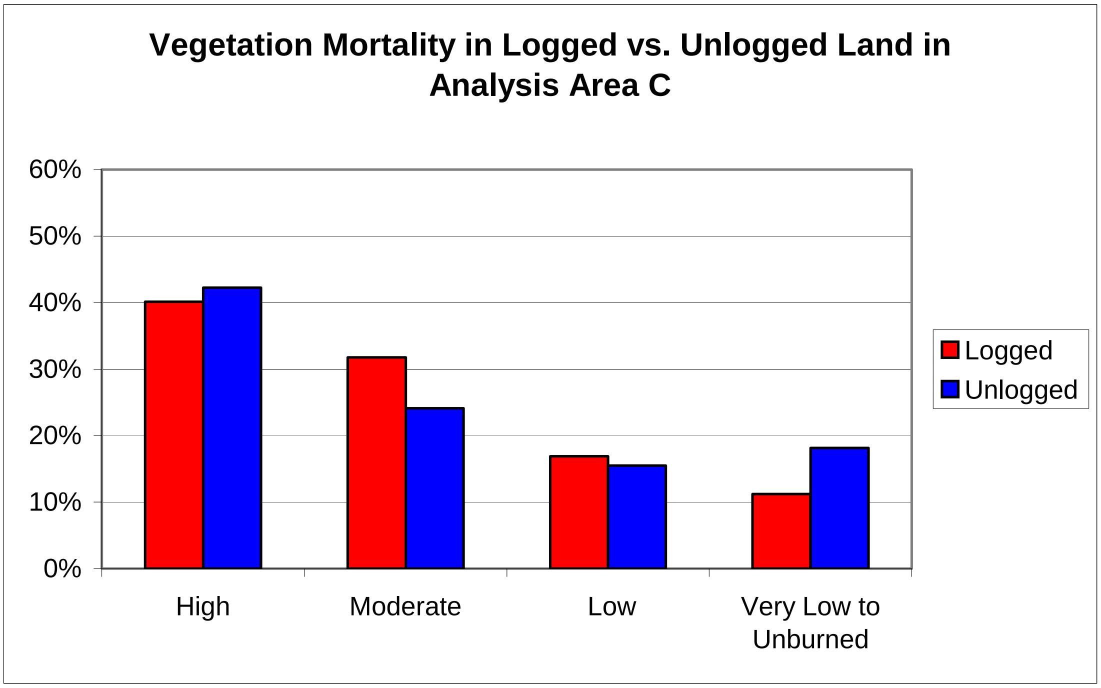

Figure 7: Vegetation mortality in logged and unlogged areas in Area C of the Biscuit Fire Complex

Several factors besides logging history may have affected how these areas burned. The majority of the logged areas in **Area A** lay along the edge of the fire perimeter where many fire lines were constructed at about the same time (date) that the fire burned into this area. The fire passed over some of those fire lines and more lines were constructed. Fire line construction is just one indication that fire suppression was active in this area at the time of the fire, influencing its progression and severity. It is also possible that firefighters conducted back-burns in this area. In **Area B**, many of the logging units were deep within the fire perimeter, where no fire lines were constructed. This indicates that fire suppression efforts were less active in this area, and perhaps the fire had more opportunity to "run its course." **Area C** contains units both along the fire perimeter and deep within it. Other factors that may have affected how these units burned include; fire weather as the fire reached the logging units, topography, vegetation type, and wind speed and direction. Unfortunately, weather-related variables cannot be accounted for in this spatial analysis.

We chose to look at the three separate analysis areas in order to limit the differences between the confounding factors described above. If we assume that the conditions in the analysis areas were similar across the landscape at the time of the fire, whether an area was logged or unlogged appears to have exerted an influence on how severely the vegetation was affected.

Vegetation mortality in areas of previous fires

The vegetation mortality caused by the Biscuit Fire Complex as it burned through areas that have burned in the past 10 years is distinctly different from the vegetation mortality in the fire area as a whole. The Biscuit Fire Complex affected 6,547 acres of land burned within the past 10 years by previous fires, but 83% of that land was in the very low to unburned severity category. Only 6% burned as high severity, 6% as moderate, and 5% as low (Figure 8). The situation was different within the area burned by the Silver Fire in 1987 (Figure 9). A slight majority of this fire area was unburned or burned with very low severity, but 53% of the area burned as high or moderate severity. This pattern is very similar to that in the Biscuit Fire Complex as a whole. However, although vegetation mortality from the Biscuit Fire Complex was heterogeneous throughout most of the Silver Fire area, a large portion of land in the southern area of the Silver Fire (just above the Chetco River, see Figure 1) burned with very low to no vegetation mortality.

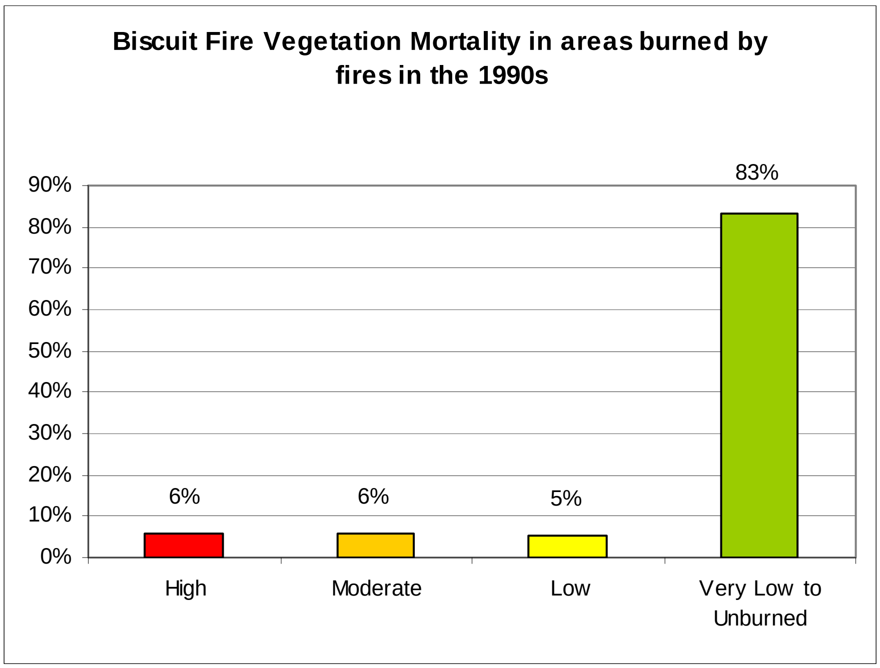

Figure 8: Biscuit Fire Complex vegetation mortality in areas burned by fires in the 1990s.

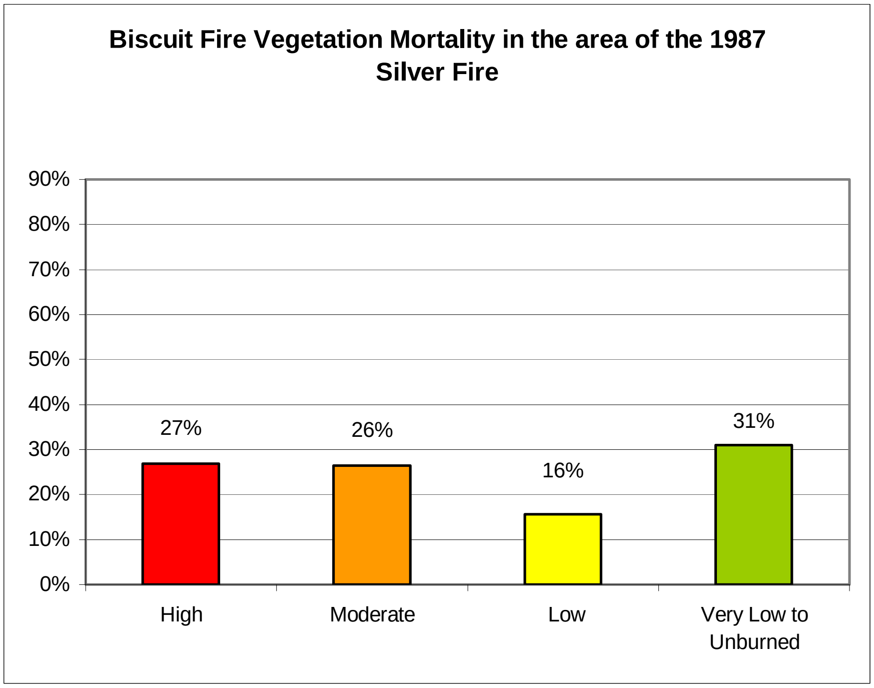

Figure 9: Biscuit Fire Complex vegetation mortality in the area of the 1987 Silver Fire

Vegetation Mortality in the Silver Fire Salvage Units

Figure 10 shows a satellite image taken after the Biscuit Fire Complex, and shows the relative locations of the Silver Fire post-fire logging units. Figures 11 and 12 show a detailed area of the cuts in the Silver Fire area both before and after the Biscuit Fire Complex. Figure 13 shows the proportion of each vegetation mortality class within those units, and can be compared to the vegetation mortality in the unlogged portion of the Silver Fire burn area (Figure 14).

Both the satellite images of the salvage units before and after the Biscuit Fire Complex (Figure 10-12) and the graph of vegetation mortality in the salvage units (Figure 13) show that the area salvage-logged after the 1987 Silver Fire burned intensely in the 2002 Biscuit Fire Complex. The unlogged portion of the Silver Fire area experienced relatively equal amounts of land burning as high, moderate, low and unburned (Figure 14). The vegetation mortality in the logged units stands out in sharp contrast to the conditions in the unlogged land that was also affected by the 1987 Silver Fire. Therefore, the fuels conditions were in the Silver Fire salvage units were probably affected by more than the fact that this area had been burned in a previous fire.

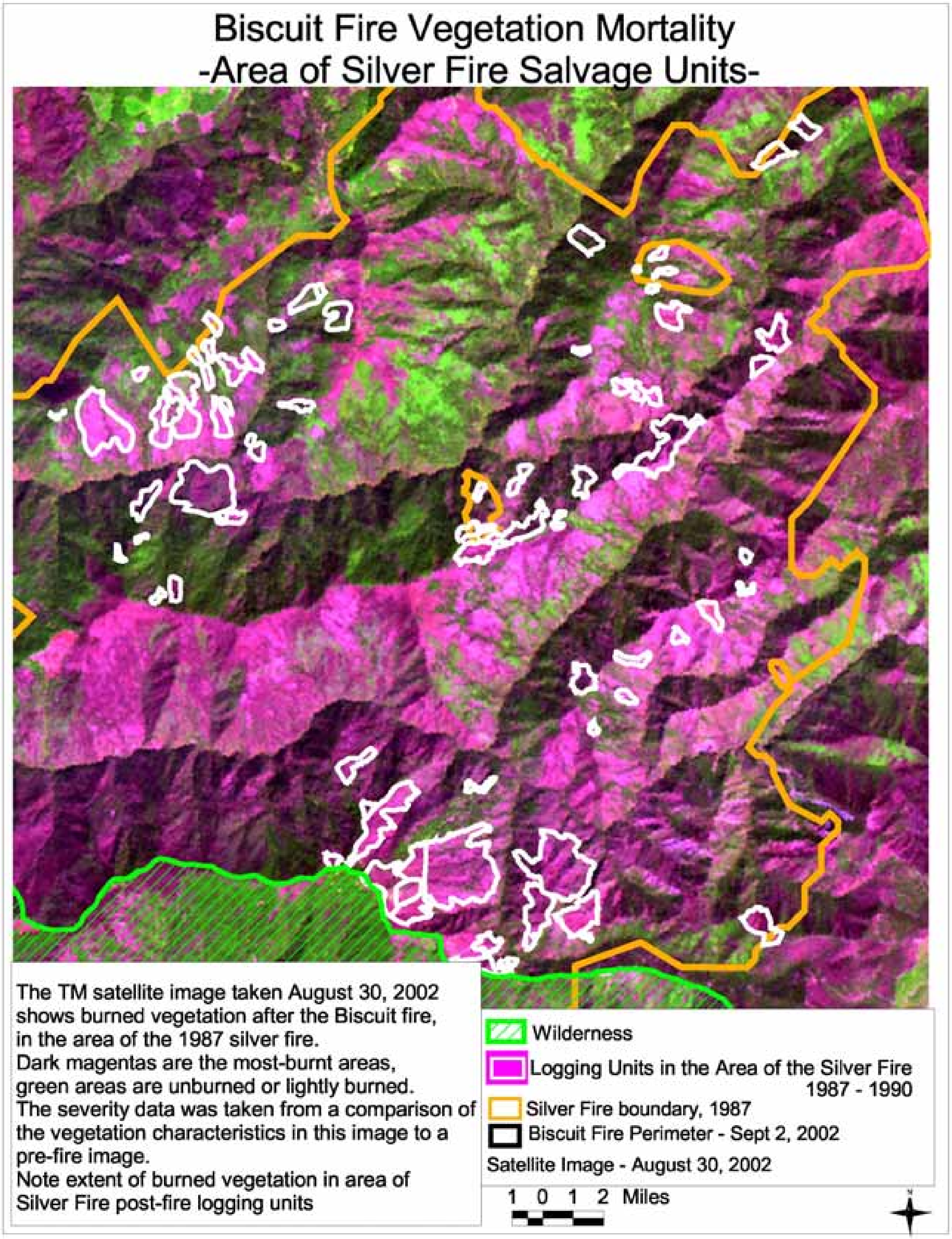

Figure 10: Vegetation Mortality in areas of salvage logging activity after the 1987 Silver Fire.

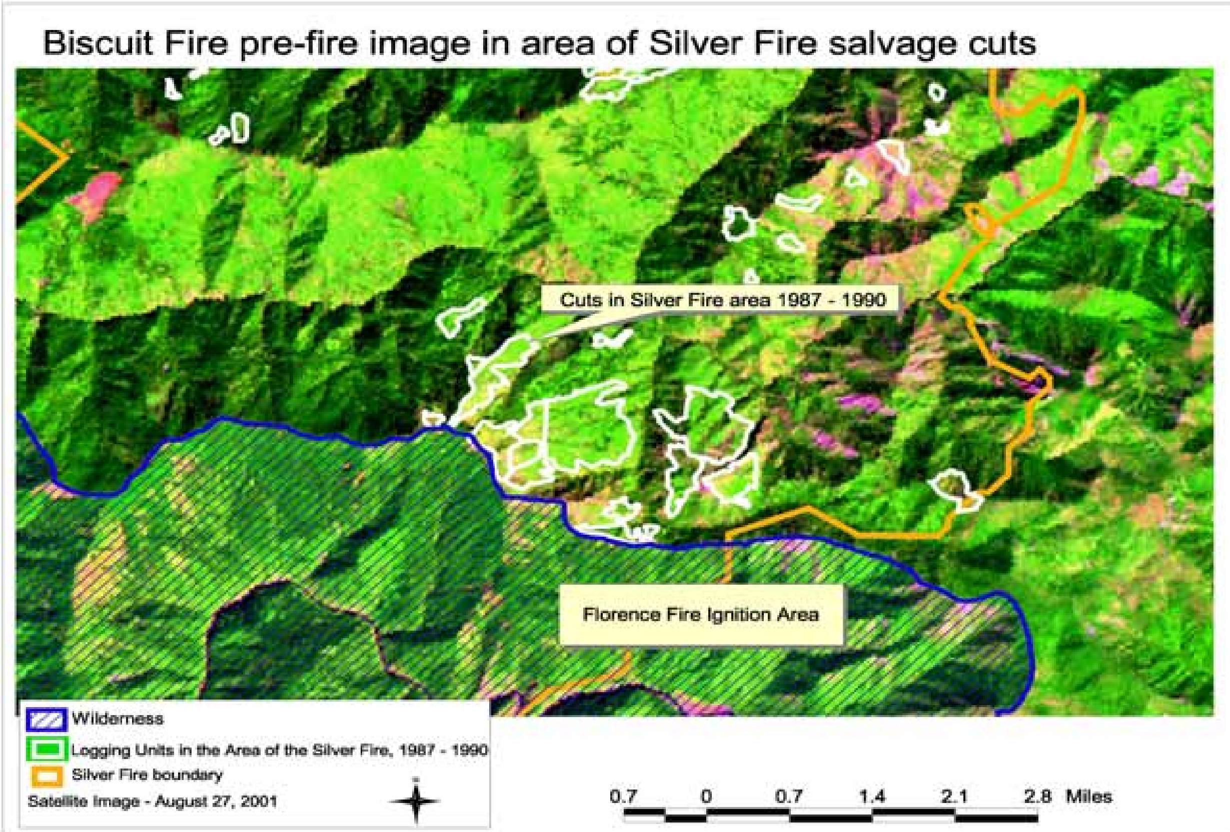

Figure 11: Detail of Silver Fire salvage logging units. Pre-fire image of the area affected by the 2002 Biscuit Fire Complex

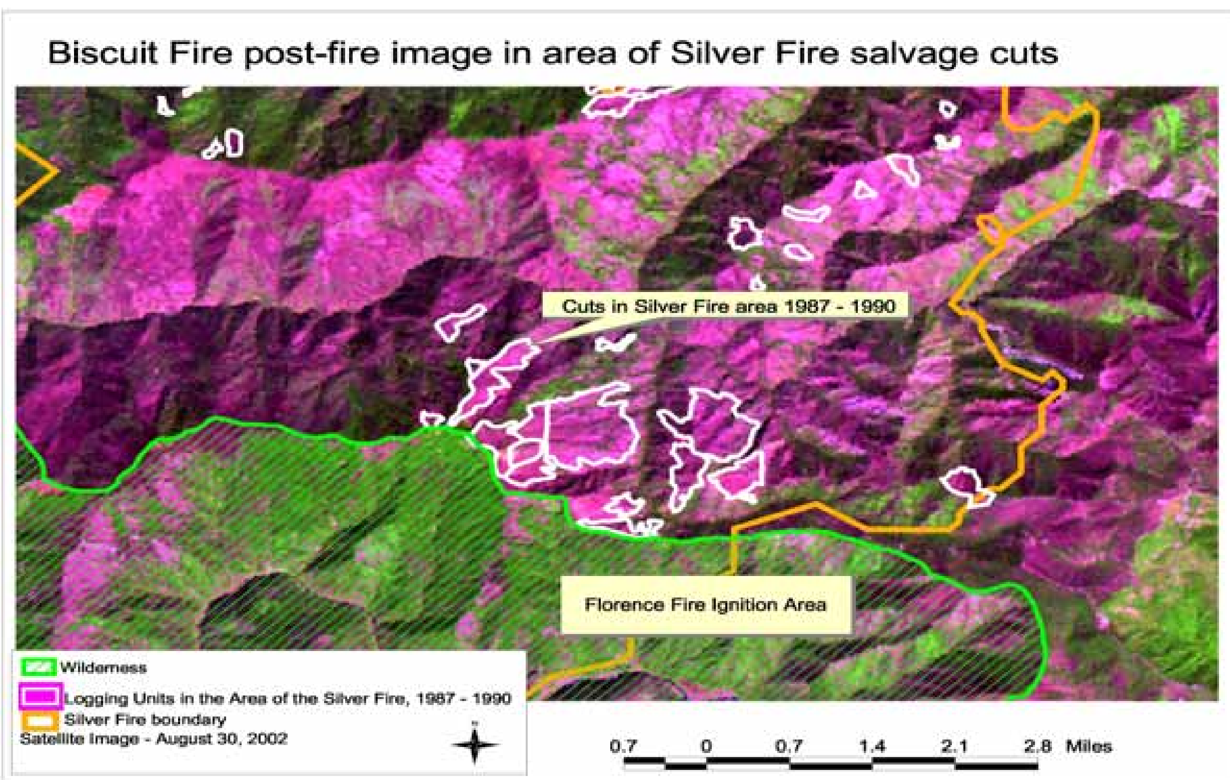

Figure 12: Detail of Silver Fire salvage logging units. Post-fire image of the area affected by the 2002 Biscuit Fire Complex.

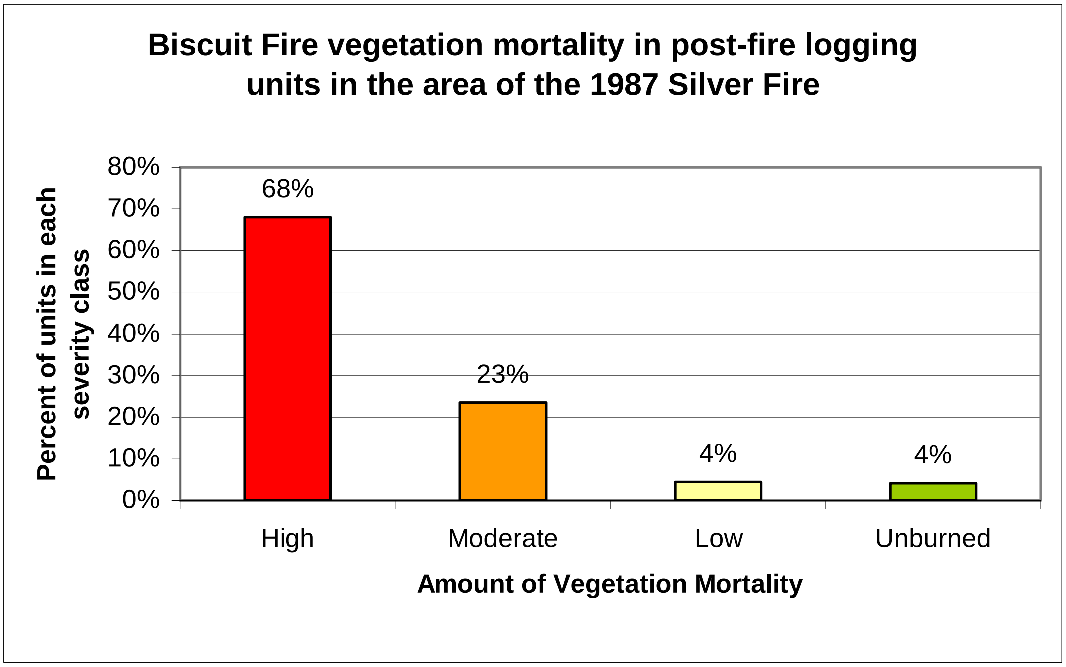

Figure 13: Vegetation Mortality from the 2002 Biscuit Fire Complex in post-fire logging units in the area of the 1987 Silver Fire. Percentages represent proportion of logging units that were high, medium or low vegetation mortality, or unburned.

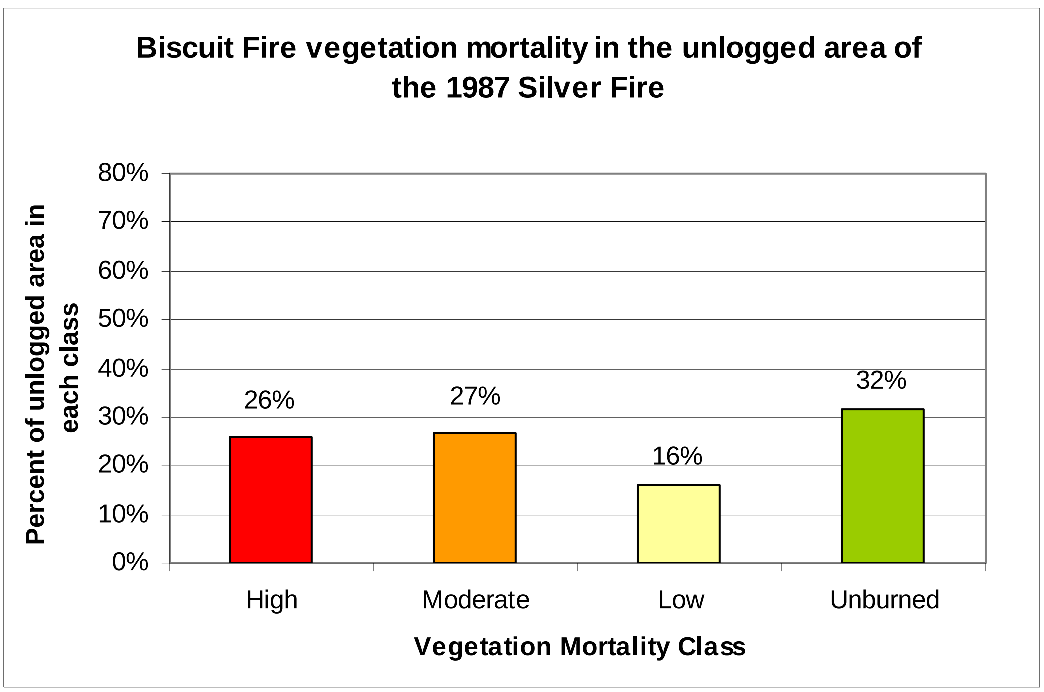

Figure 14: Vegetation Mortality from the Biscuit Fire Complex in the unlogged area of the 1987 Silver Fire. Percentages represent proportion of unlogged area that experienced high, medium or low vegetation mortality, or unburned.

Vegetation mortality and management designation

In order to look for differences in fire effects between different management designations, we have to create a base for comparison, in this case, the vegetation mortality within the fire perimeter as a whole. A third of the area within the Biscuit Fire Complex perimeter experienced very low vegetation mortality or was unburned, and an additional 12% experienced low vegetation mortality (Figure 15). 56% of the fire area experienced either high or moderate vegetation mortality.

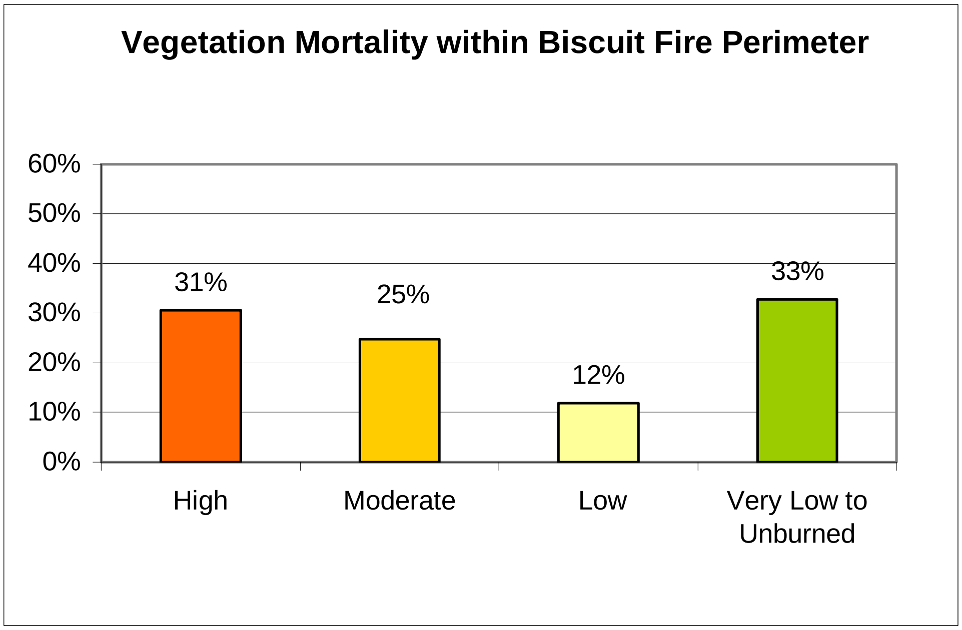

Figure 15: Vegetation mortality break-out within the entire Biscuit Fire Complex perimeter

The graphs below show the break out of fire severity within each of the management types. Note that the percentages do not relate to percent of the total fire area, but rather to the percent of the management type in question.

Inventoried Roadless Areas

Within the Forest Service Inventoried Roadless Areas, slightly more land (34%) occurs in the high vegetation mortality class than in the other mortality classes (Figure 16). But this is not significantly different from the 31% of the entire fire area that had high vegetation mortality. The biggest difference is in the moderate vegetation mortality category (31% of the roadless areas and 25% for the entire fire area). But these differences are relatively minor. Overall, the roadless areas burned similarly to the fire as a whole.

There are several possible reasons why vegetation within the roadless areas experienced slightly greater mortality than the average for the fire as a whole. The first reason is that the fire burned through most of the roadless lands in the initial days of the fire, during a very unusual weather anomaly when the fire was burning ferociously. The weather conditions were less conducive to intense fire behavior later in the progression of the fire -- when it was burning closer to its final perimeter, outside of the roadless areas. Another significant factor is that many of the roadless areas have soils derived from ultramafic rocks. These soils tend to be shallower than soils from other parent materials. As a result, the vegetation within these areas dries out more during summer droughts and in turn is more flammable than vegetation growing on more productive substrates.

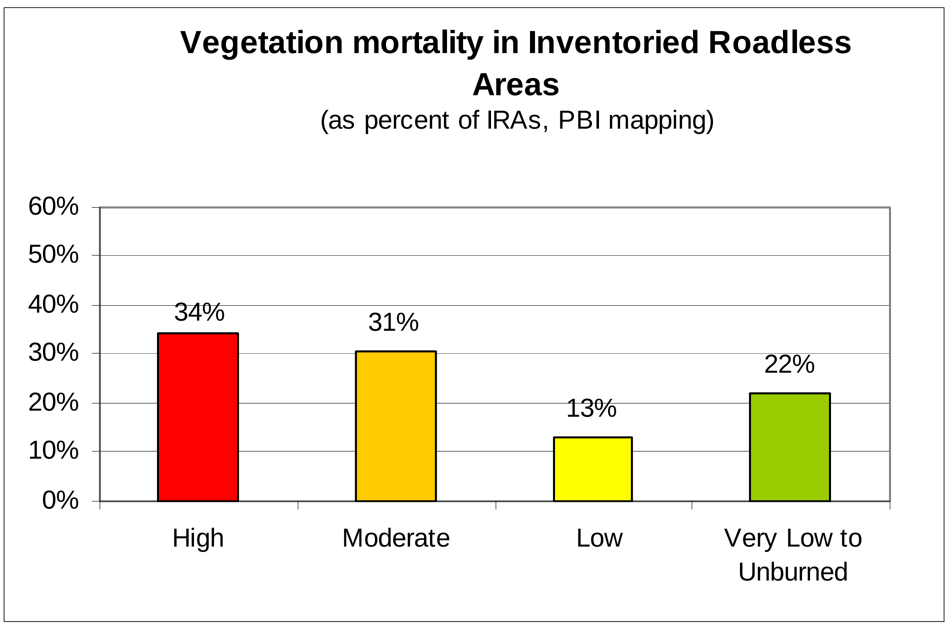

Figure 16: Vegetation mortality in Inventoried Roadless Areas

Late Successional Reserves

A greater proportion of land burned as “high” and “moderate” in Late Successional Reserves than in the fire area as a whole but the difference between the LSRs and the entire fire were slight (Figure 17). A smaller proportion was “unburned.”

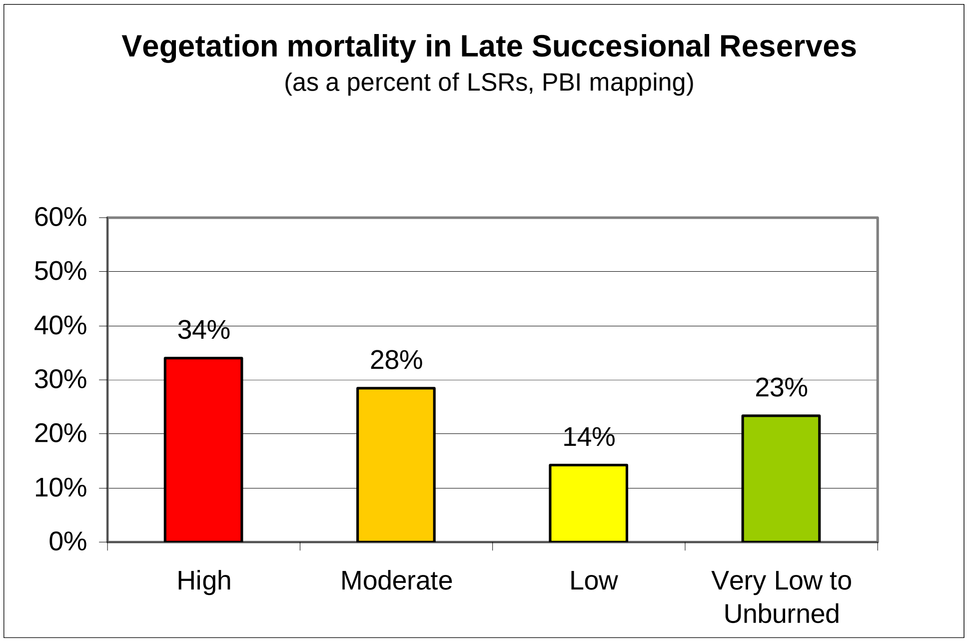

Figure 17: Vegetation mortality in Late Successional Reserves

Key Watersheds

A slightly greater proportion of land burned as "high" and "moderate" in the Key Watersheds than in the fire area as a whole (Figure 18). The Key Watersheds burned similarly to the LSRs. A smaller proportion was "unburned" in the Key Watersheds.

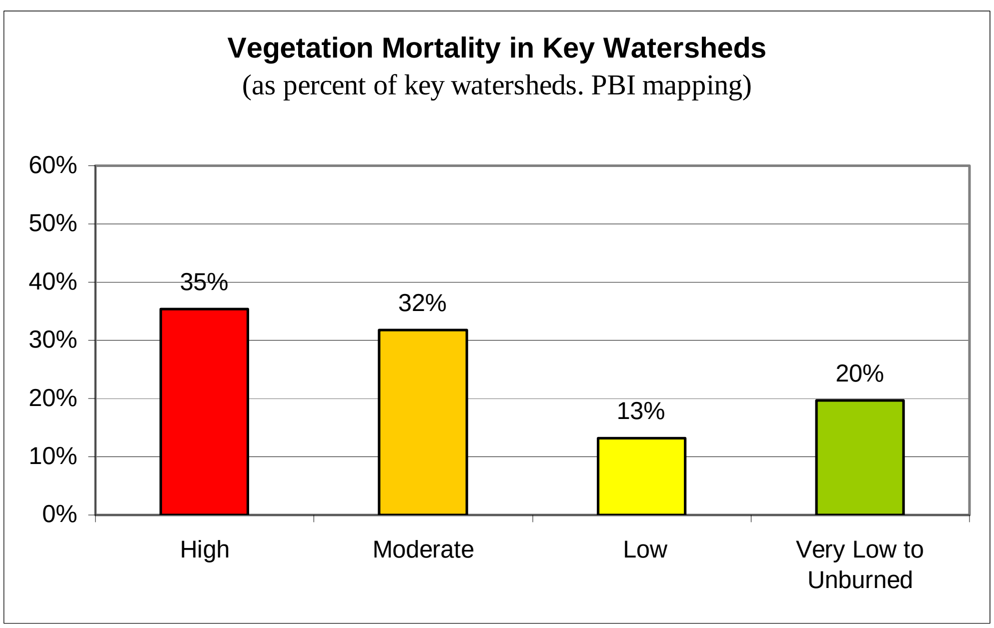

Figure 18: Vegetation mortality in Key Watersheds

Matrix Lands

The pattern of vegetation mortality in the matrix lands was very similar to that of the fire area as a whole (Figure 19).

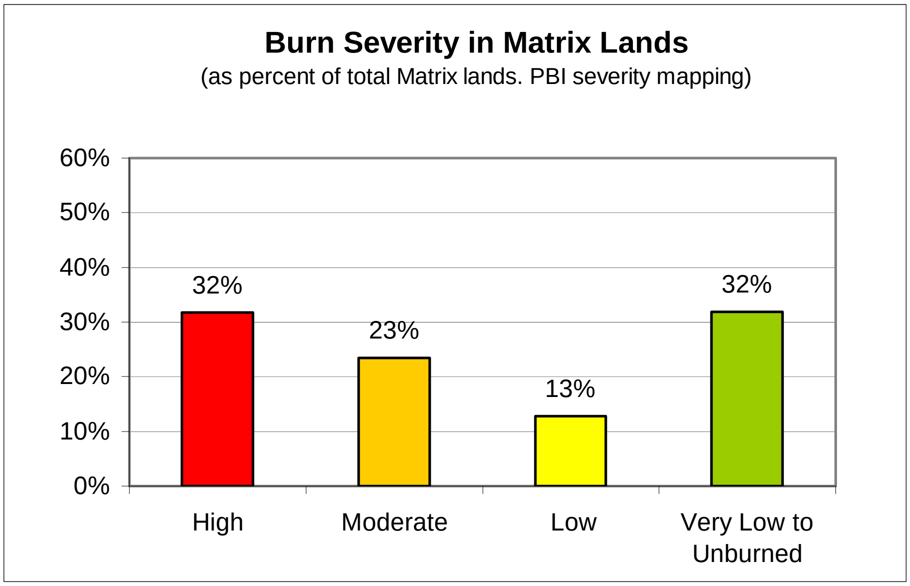

Figure 19: Vegetation mortality in Matrix lands

Vegetation mortality in ultramafic soil areas

A large amount of the land burned in the Biscuit Fire Complex is characterized by ultramafic soils (also called serpentine soils). The mineral content in these soils often causes the vegetation growing on these soils to be stunted and grow more sparsely than in other soil types. As discussed above, these ultramafic soils tend to be shallower than soils from other parent materials. As a result, the vegetation within these areas dries out more during summer droughts and in turn is more flammable than vegetation growing on more productive substrates. Our analysis of vegetation mortality in the ultramafic soils indicates that a much greater proportion of the vegetation on ultramafic soils experienced high and moderate mortality than the vegetation on the other soil types (Figure 20).

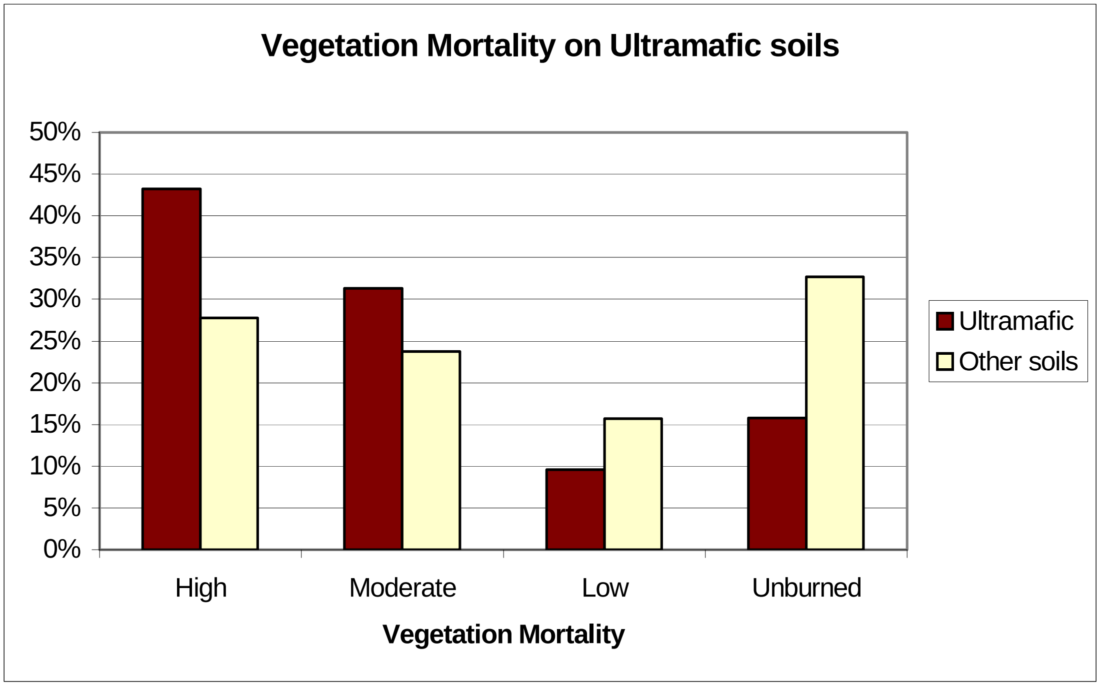

Figure 20: Vegetation mortality on ultramafic soils compared to on other soil types within the Biscuit Fire Complex perimeter

One other possible explanation for this distinct trend towards greater mortality on ultramafic soils could be attributed to difficulties in the satellite image interpretation, since the pre-fire image of the ultramafic soil area has a darker reflectance, somewhat similar to that of burned land. However, our image differencing techniques should compensate for this, since the vegetation mortality classification is the result of determining the *change* between a pre-fire and post-fire satellite image. Actual landscape level factors are probably causing greater mortality of vegetation on ultramafic soils. Other factors that may have affected how ultramafic soils burned include; fire weather, topography, vegetation type, and wind speed and direction. Unfortunately, weather-related variables cannot be accounted for in this spatial analysis.

Conclusions

As is the case with most wildfires, the Biscuit Fire Complex did not affect all parts of the landscape uniformly. Nearly as much land within the fire perimeter burned with high vegetation mortality as with very low vegetation mortality, and all gradations in between were present. Despite the heterogeneity of vegetation mortality caused by the fire, some conclusions can be made from where the different levels of mortality occurred.

The lowest vegetation mortality occurred on the western flank of the fire and in some areas within the fire perimeter. A factor affecting lower vegetation mortality along the western edge of the fire is the moister conditions in this part of the forest. Also, the western edge of the fire burned late in the fire's progression and weather conditions may have resulted in less intense fire behavior. In addition, the edges of the fire perimeter experienced most intensive fire suppression efforts. The fuels could have been altered from suppression activities such as back-burning and this may have affected how the vegetation burned in this area.

The unburned and lightly burned areas within the Biscuit Fire Complex perimeter correspond closely to areas burned within the past 20 years. When broken down by decade, the land that burned within the past decade exhibited 83% very low or no vegetation mortality. Although the area burned by the 1987 Silver Fire exhibited a similar pattern of vegetation mortality to that in the fire area as a whole, large portions of land previously burned by the Silver fire burned lightly in the Biscuit Fire Complex. The difference in severity between recently burned areas and the fire area as a whole is greater than differences due to any other landscape condition examined in this analysis, indicating that previous burns have a strong influence on subsequent burns.

Past logging activity appears to have exerted an influence on the vegetation mortality caused by the Biscuit Fire Complex. The difference in vegetation mortality in logged v. unlogged areas was strongest in analysis Area B, where there was a much greater proportion (26% higher) that burned as high vegetation mortality in logged areas than in the unlogged areas. This trend is also present in Area A. In Area C there was slightly less high mortality in logged than unlogged areas, but a slightly greater amount of moderate mortality burn in logged than unlogged areas and a greater proportion of unburned land in unlogged areas. Overall, these figures demonstrate that past logging potentially has a strong influence on subsequent vegetation mortality due to wildfire, and that vegetation mortality is greater in logged than in adjacent unlogged areas.

The areas that were salvage-logged after the 1987 Silver Fire show a stronger trend towards high mortality burn than that seen in the other historically logged areas. The proportion of land occurring as high mortality in these areas was 68%, compared to a maximum of 50% high mortality in the logged areas in Analysis Area B. Also, an overwhelmingly greater proportion of land experienced high vegetation mortality in the logged areas than in the unlogged areas also affected by the Silver Fire.

The differences in vegetation mortality between Inventoried Roadless Areas, Late Successional Reserves and Key Watersheds are insignificant. This could partly be due to the fact that much of the land in the analysis areas overlaps (i.e. much of the land that is Inventoried Roadless Area is also Late Successional Reserve or in a Key Watershed). Matrix lands, which don't overlap with Roadless Areas and Late Successional Reserves, exhibit a slightly different breakout of effects, with more land occurring as unburned, and less land occurring as moderate. This could be due, in part, to the location of the matrix lands within the fire area. Most of the matrix lands are on the edges of fire perimeter, where there tended to be less vegetation mortality overall, due to the possible driving factors discussed above.

In conclusion, the results of our analysis indicate that landscape conditions, including incidence of past fires, past logging, salvage logging, and ultramafic soils, exerted an influence on how severely the vegetation burned in the Biscuit Fire Complex. However, this spatial analysis just looks at immediate post-fire vegetation mortality, and is just a first step in understanding the ecological consequences of the fire. The long-term effects on the entire ecosystem in the fire area will not be determined until several years from now. The condition of the vegetation and soils should be monitored throughout the fire area over the next two decades, and, as indicated by our analysis, areas of previous burns, past logging and ultramafic soils should receive special attention.

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