Burn Severity and Land Cover Transition in the McNally Fire

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Introduction to Remote Sensing
Geography 58 - Winter 2011
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Introduction

Remote sensing techniques can be used to estimate burn severity in areas affected by wildfires. The Normalized Burn Ratio (NBR) is a radiometric measure of burn severity that was developed specifically to be calculated from Landsat TM image data.[1] One way that we might evaluate whether NBR accurately measures burn severity is to look at patterns of regrowth after a fire and see whether low severity areas perform differently than high severity areas. To test this approach, I looked at the McNally Fire, which burned 150,000 acres of Sequoia National Forest in 2002.

Background

Wildfires are almost a regular occurrence in California. Fires can take human lives, destroy property and natural resources, but they are also part of the natural ecology. The plants and animals native to fire-prone areas adapt to a fire regime, and in some cases thrive in the years following a natural wildfire. It is important for us to study fire ecology both in order to protect ourselves and in order to understand the part that fire plays in our wild ecosystems.

Remote sensing can play several roles in the management and study of fire. It can be used to assess the aftereffects of fires, to provide data during active fire events, and to assess fuel conditions in fire management areas. In this paper, I will focus on the first area; specifically, the use of Landsat imagery to create burn severity maps. Burn severity is an important basic statistic in fire research, and has uses such as supporting rehabilitation efforts and guiding researchers on the ground investigating ecological impacts of a fire. The ability to use Landsat images to quickly and easily create accurate burn severity maps is a boon, especially when a fire covers a large and potentially inaccessible wilderness area.

Methods

From Glovis, I acquired Landsat 4-5 TM images of the Sequoia National Forest area (path 41, row 35) for the following dates: September 1, 2001, September 20, 2002, and September 10, 2010. These images were windowed to a 1300 x 1800 pixel region centered on the fire area.

Burn severity was estimated using differenced NBR between the pre-fire (2001) and post-fire (2002) images. First, the NBR for each date was computed in Idrisi with the OVERLAY tool, by using bands 4 and 7 according to the NBR formula: NBR = (R4 – R7) / (R4 + R7).

Then the 2002 NBR image was subtracted from the 2001 NBR image to produce the differenced NBR (dNBR). The dNBR values were also scaled by 1000 to put them into a more convenient range.

Since burn severity is only meaningful within the fire area, I next masked out the parts of the image outside the fire boundary. The Monitoring Trends in Burn Severity (MTBS) project at the USGS provides vector files defining the bounds of recent fires, including the McNally fire. I converted that vector file to a raster image of the fire extent, and then used the image calculator function with that as an image mask to select the relevant parts of the dNBR image.

Finally, I reclassified the dNBR image into discrete burn severity classes rather than a continuous range of values. I used the following ranges, which were taken from [1].

- Unburned: < 100
- Low: 100 to 255
- Moderate Low: 256 to 410
- Moderate High: 411 to 660
- High: > 660

To determine the land cover within the fire area, I performed unsupervised classifications of the 2001, 2002, and 2010 maps in Idrisi with the ISOCLUST module. In all cases, the classification used Landsat bands 1, 2, 3, 4, 5 and 7, with 10 iterations and 8 clusters. The clusters were then assigned to the following four classes:

1. Rock / Bare Ground
2. Chaparral / Open Conifer
3. Mixed Conifer
4. Recent Burn

The USGS Northern Rocky Mountain Science Center hosts a series of reference photographs for measuring Composite Burn Index (CBI), a burn severity measure that complements NBR.[2] In the Sequoia National Forest region, they identify Chaparral/Open Conifer and Mixed Conifer as the primary land cover classes[1], so I chose to target those two as the main classes in my

[1]In fact, the CBI reference photos for the Sequoia National Forest region are almost all from the McNally Fire.

unsupervised classification. There is a prominent rocky outcrop in the south eastern corner of the image (outside the fire area), so that became the third class. Only the 2002 image uses the Recent Burn class.

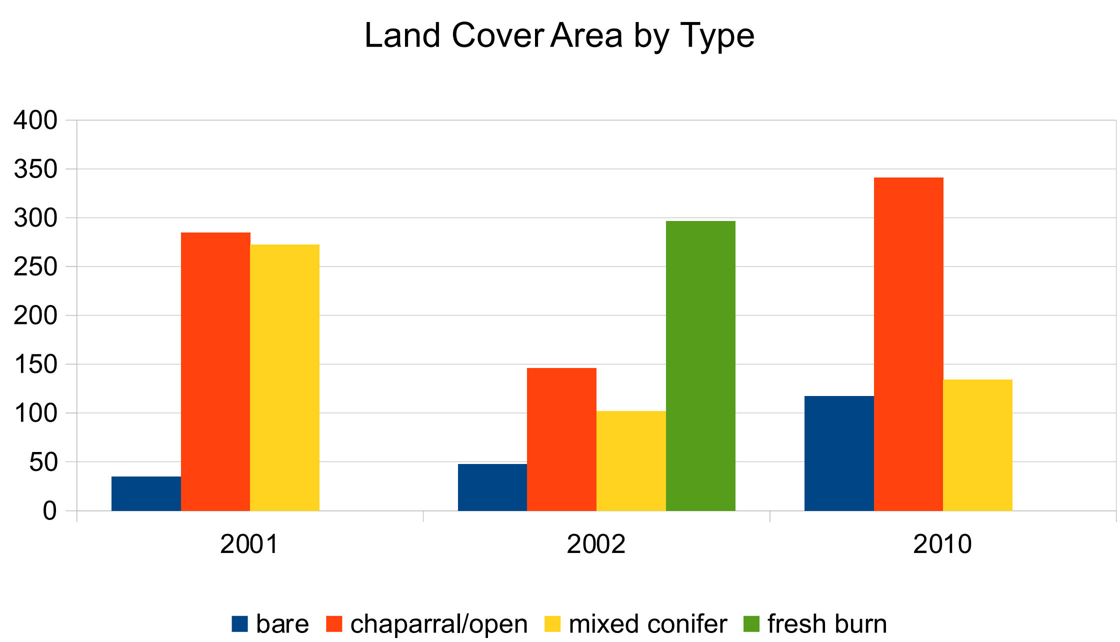
After classifying the full images, I masked the classified images to the fire area using the same method as with the dNBR image.

Results

First, without regard to burn severity, how did the land cover change immediately after the fire and in the years since? Table 1 shows the area for each land cover type within the fire boundary in square kilometers.

	2001	2002	2010
Rock / Bare Ground	35	48	117
Chaparral / Open Conifer	285	146	341
Mixed Conifer	273	102	134
Recent Burn	0	297	0

Table 1 - Land Cover Area by Type in Square Kilometers



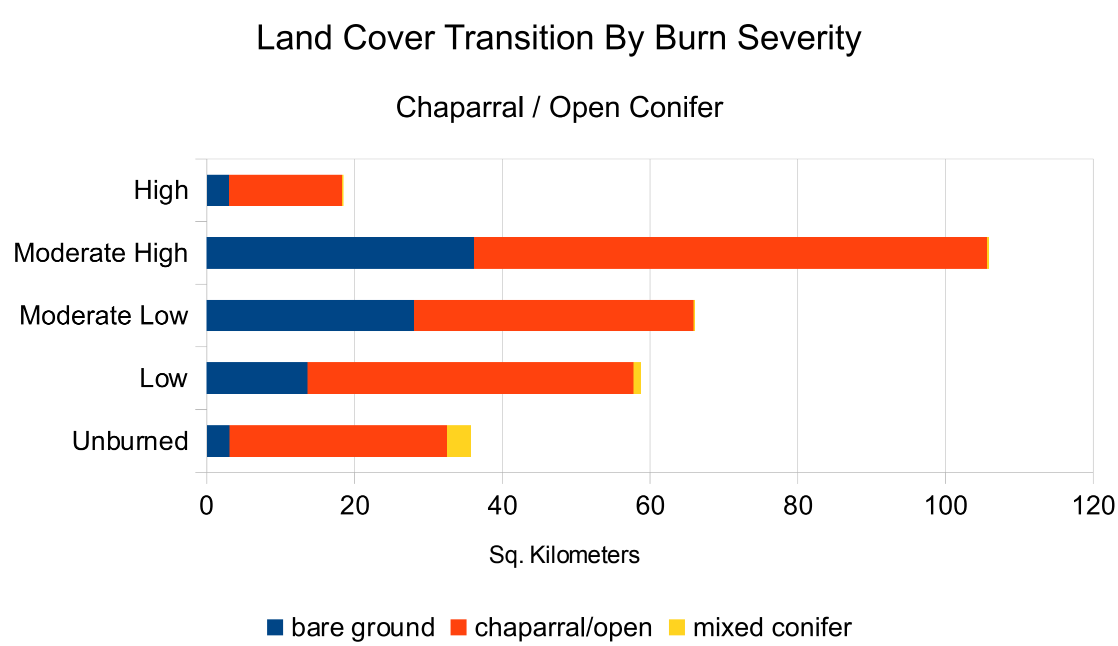
Vegetation area dropped dramatically after the fire, as expected. Eight years later, the Mixed Conifer area has increased slightly, possibly regrowth of trees that lost foliage but did not die. More of the ground remains bare compared to before the fire. Area classified as Chaparral and Open Conifer has rebounded, surpassing its original area.

Table 2 shows areas broken down by original land cover type, recent land cover type, and burn severity class.

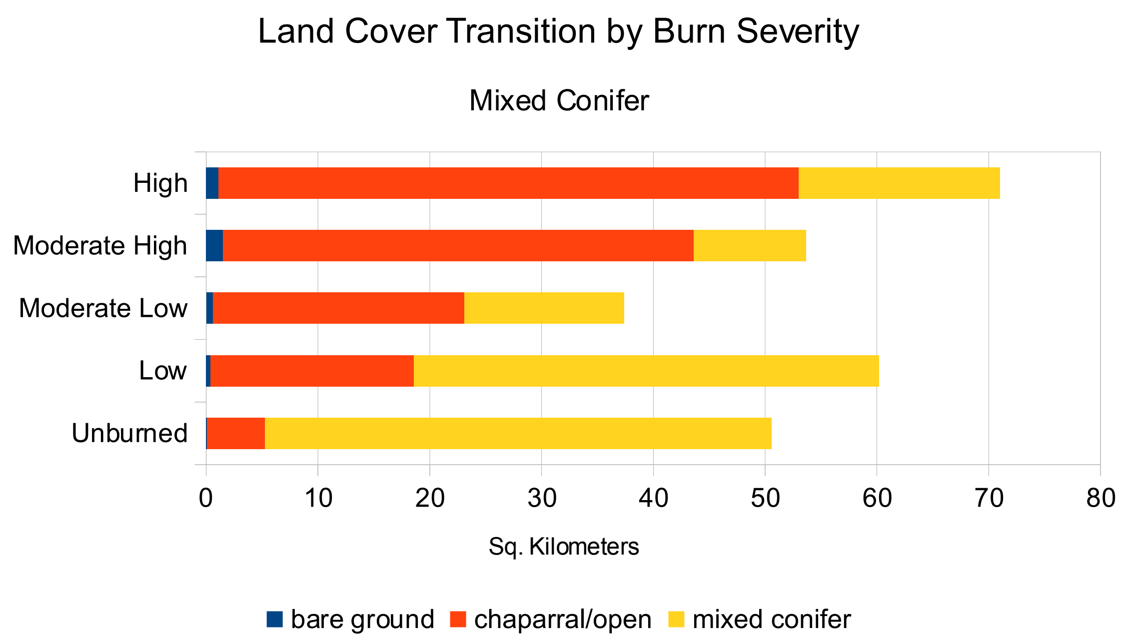
2001 class	2010 class	Unburned	Low	Mod. Low	Mod. High	High
bare ground	bare ground	7.86	11.27	8.79	1.62	0.01
bare ground	chap./open	2.68	1.52	0.61	0.33	0.02
bare ground	mixed	0.24	0.13	0.03	0.01	0.00
chap./open	bare ground	3.11	13.70	28.05	36.19	3.04
chap./open	chap./open	29.39	44.07	37.82	69.42	15.25
chap./open	mixed	3.25	1.00	0.16	0.23	0.15
mixed	bare ground	0.11	0.39	0.64	1.50	1.13
mixed	chap./open	5.15	18.19	22.47	42.11	51.89
mixed	mixed	45.31	41.60	14.29	10.04	17.98

Table 2 – Land Cover Transitions and Burn Severity

Land that began as bare ground mostly stayed bare ground, and almost none of it had a high burn severity (which makes sense: nothing to burn). So let us turn to land that was initially covered with Chaparral and Open Conifer.



This chart shows what the land cover was in 2010 for land that was classified as Chaparral / Open Conifer in 2001, broken down by burn severity. For example, among land that was initially chaparral or open conifer, more had a moderately high burn severity than any other severity. In those areas with moderately high severity, a large chunk remains bare ground, with the rest having returned to chaparral or open conifer (in spectral appearance, at least). With the possible exception of the high severity areas, there does not appear to be a significant difference in the regrowth performance between different burn severities. One explanation might be that we are seeing plants that have adapted to wildfire by sprouting and growing quickly in burned areas; high burn severity just means that more competitors were burned off.



Land that was originally mixed conifer (denser, more mature forest) shows a different pattern. We see a much greater transition to chaparral or scattered trees, and this effect is more noticeable in the higher severity burn areas. In the low burn severity areas, more land has returned to mixed conifer status than changed to chaparral.

Conclusions

Overall, the way in which the land cover types have transitioned eight years after the McNally Fire matches fairly well with what we would expect based on the dNBR estimate of burn severity. This tends to support the differenced NBR as an accurate measure of burn severity.

Here are two refinements that could be applied to this method: one related to the NBR and one related to the unsupervised classification.

The burn severity classes that I used were somewhat arbitrarily based on dNBR values from other fires; ideally, an expert analyst would select dNBR values specific to a particular fire. Also, the MTBS actually uses a more sophisticated NBR calculation for their burn severity maps that they call “Relative differenced NBR”, which takes into account some of the pre-fire conditions. Using the Relative dNBR would improve the classification of burn severity, and possibly address the large skew towards (in the case of mixed conifer) and away from (in the case of chaparral / open conifer) the high burn severity class.

The unsupervised classification presented here gave reasonably good results, but it was deliberately kept very simple. I am left wondering, for example, whether there is a detectable spectral difference between mature chaparral and new post-fire regrowth.

References

[1] Key, C.H., and Benson, N.C. 1999. Measuring and remote sensing of burn severity: the CBI and NBR.
[2] Composite Burn Index Photo Series. http://www.nrmsc.usgs.gov/science/fire/cbi