Using differenced hyperspectral data and spectral mixture analysis to understand fire effects with the Rim Fire

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Introduction

Examining fire effects via remote sensing in an accurate and broadly applicable manner is important to immediate post-fire rehabilitation, as well as characterizing long-term trends in fire behavior at an ecosystem scale. This has typically been done through the use of Landsat and the Differenced Normalized Burn Ratio (dNBR) index. The availability of pre-fire AVIRIS data over the Rim Fire creates the unique opportunity to compare pre- and post-fire hyperspectral images. Although calculating dNBR through hyperspectral data is possible, it might not be maximizing the available information in the high-dimensional image cube. The Multiple Endmember Spectral Mixture Analysis (MESMA) algorthim is one of the most promising means of characterizing fire severity using the full hyperspectral data cube. In this study, we tested:

1) Whether dNBR or MESMA derived metrics better correlate with Geo Cumulative Burn Index (GeoCBI) plot values;

2) Whether having pre- and post-fire MESMA results gives additional predictive power of GeoCBI plot value over just post-fire MESMA;

3) Ways to optimize MESMA results for determining burn severity.

Methods

AVIRIS data pre-processing is summarized in Stravos *et al.* (in progress) and pre-processed images are available at http://wildfire.jpl.nasa.gov/. The June 2014 and November 2014 mosaics available on the website were used for this study. After pre-processing, noisy bands were removed from further consideration either due to their correspondence with known atmospheric absorption windows or clear artifacts of atmospheric correction. The image analysis process is documented in the flow chart below:

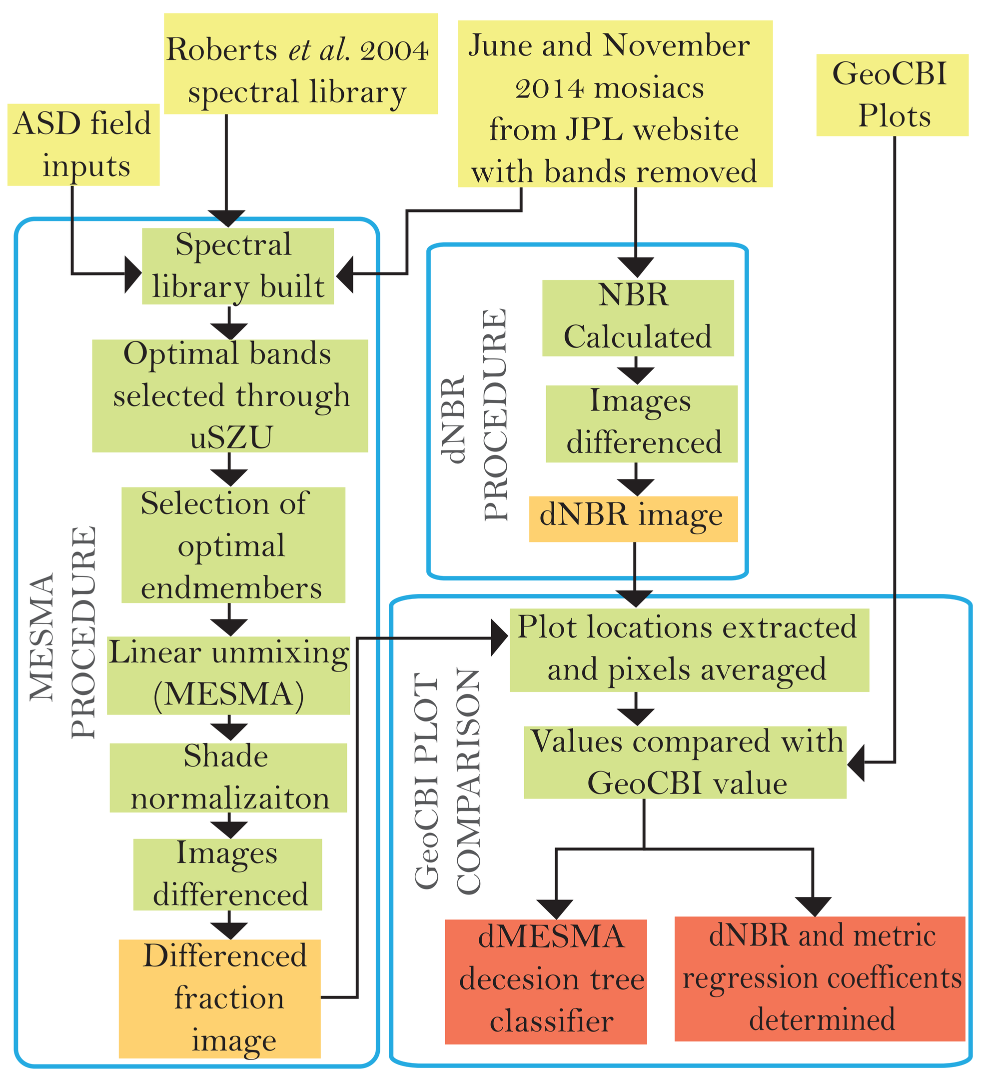

Figure 1. Flow Chart of Methods. Note that uSZU process is documented in Somers and Asner 2013 and the wavelengths selected for dNBR calculations are those recommended in van Wagendonk et al. 2004.

Results

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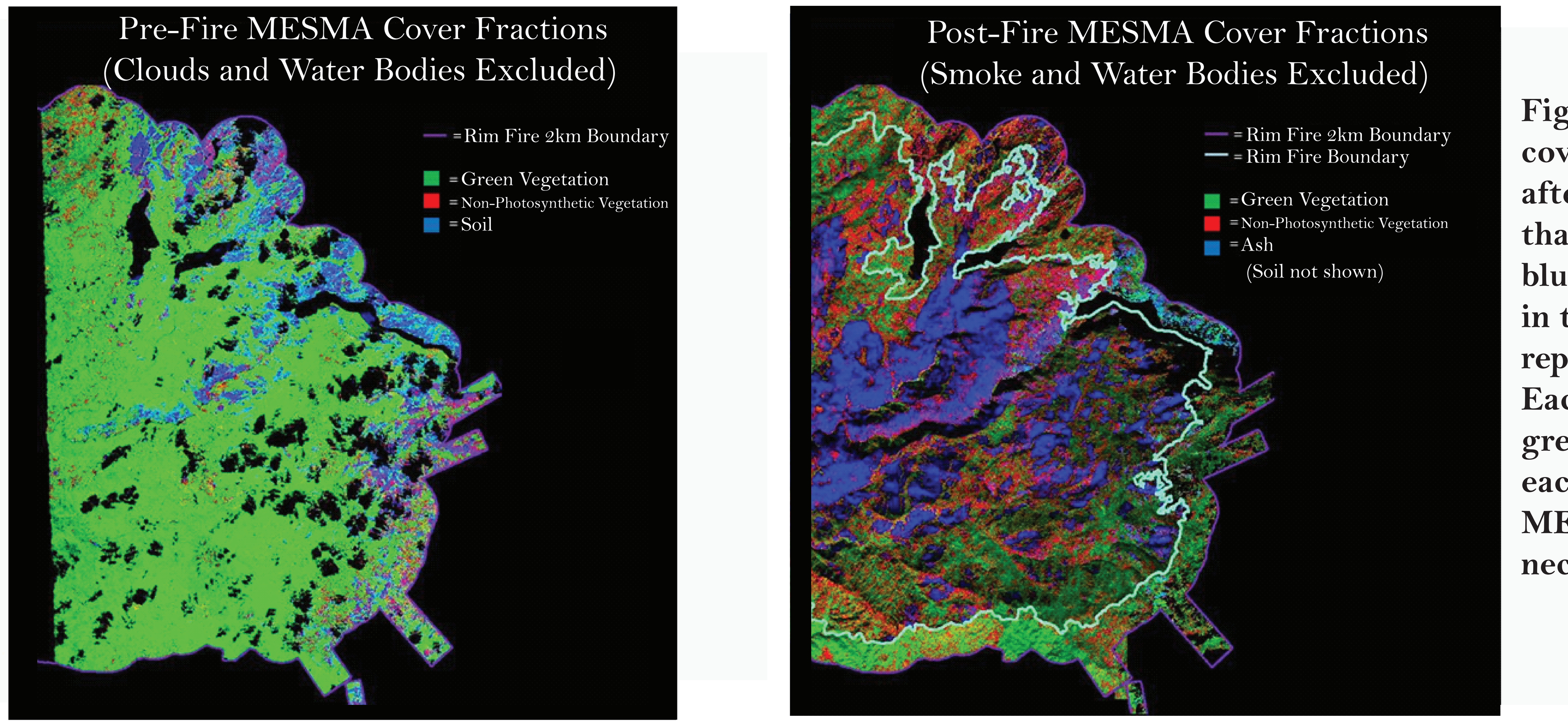

Figure 2. MESMA derived cover fractions before and after the Rim Fire. Note that in the before image blue represents soil whereas in the after image blue represents ash cover. Each pixel represents a red, green, and blue mixture of each class as determined by MESMA, and not necessarily a pure class.

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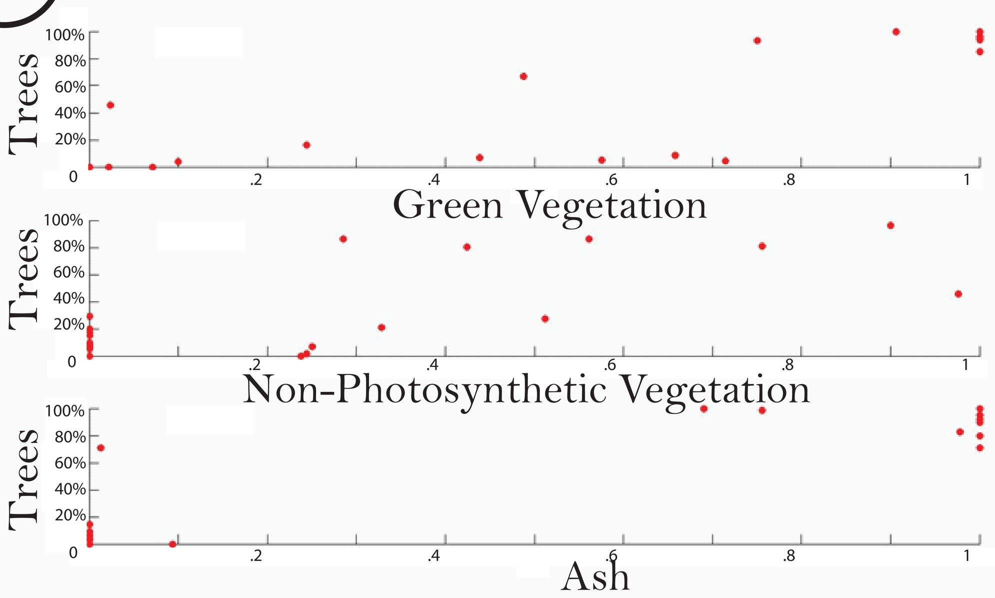

Figure 3. Percentage green, brown, and black trees from field validation plots versus MESMA derived post-fire fraction of pixel cover. Using a linear regression r^2 values are: .75 (top), .57 (middle), and .84 (bottom)

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Table 1. Pre-fire MESMA cover of the GeoCBI plots. A majority of plots were 100% green vegetation cover.

	Green Vegetation	Non-Photosynthetic Vegetation	Soil
Mean	93%	4%	2%
Max	100%	31%	27%
Min	69%	0%	0%

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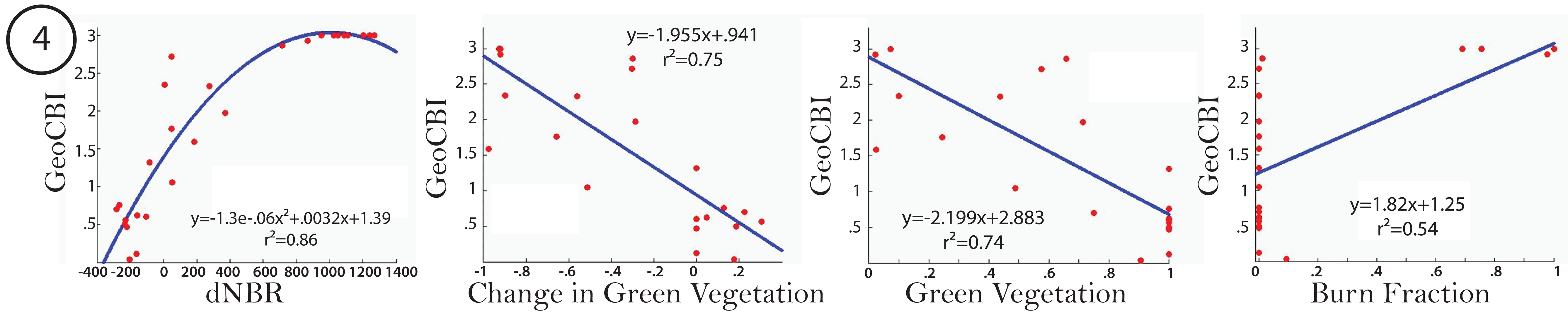

Figure 4. Four figures comparing GeoCBI (y-axis) and dNBR and three MESMA derived metrics. A GeoCBI value of 0 indicates no fire effect, below 1.5 indicates low severity, between 1.5 and 2.5 moderate severity, and above 2.5 high severity. For the MESMA derived indices, units are fraction of pixel cover post-fire or fraction of pixel cover change. Burn fraction is calculated by dividing the ash cover by the sum of the green vegetation, non-photosynthetic vegetation, and ash cover. A quadratic fit was chosen for dNBR as recommended by van Wagendonk et al. 2004. A linear fit was chosen for all MESMA derived metrics based upon theory.

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Table 2. Average change in pre- and post-fire MESMA cover fraction percentages of the ground validation plots separated by burn severity as determined by the GeoCBI value.

	Low Severity	Medium Severity	High Severity
n	11	5	11
Mean change in green vegetation	5%	-68%	-85%
Mean change in non-photosynthetic vegetation	-1%	68%	10%
Mean change in soil	-5%	0%	-1%
Mean change in ash	1%	0%	77%

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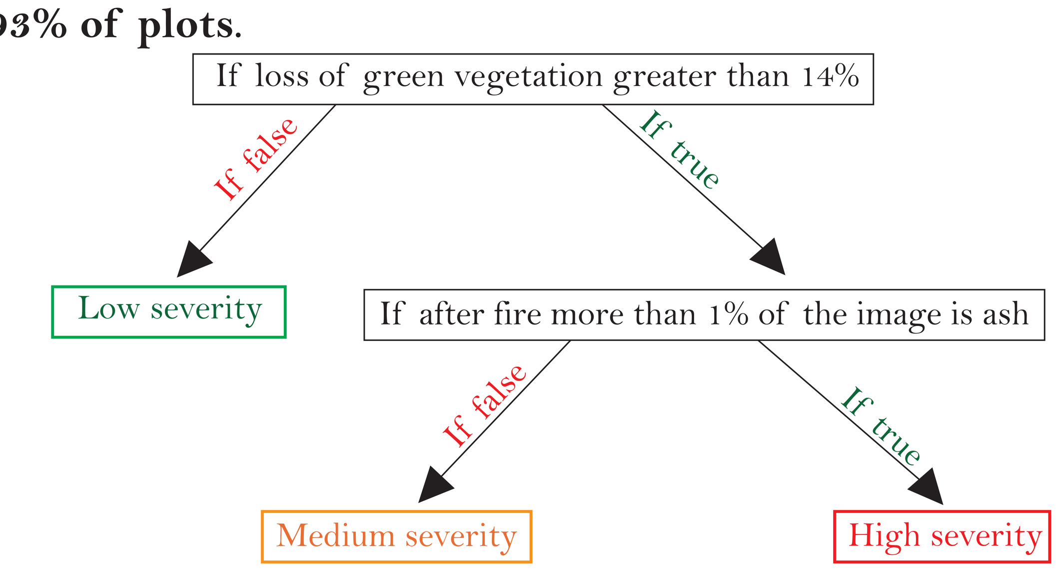
Figure 5. Decision tree for classifying fire severity as determined by GeoCBI, using differenced MESMA cover fractions. No pruning or validation was possible given the limited number of GeoCBI plots. However, this tree correctly identified the severity of 93% of plots.



Conclusions

- dNBR had the highest level of correlation with GeoCBI.

- dNBR has several problems (extensively documented in Lentile *et al.* 2009), many of which MESMA classifications do not share. In this study the MESMA derived green vegetation cover fraction corresponds linearly with GeoCBI and does not appear to show saturation at the highest severities (as opposed to dNBR).

- Differencing the pre- and post-fire MESMA classes did not create a statistically significant gain in predictive power of GeoCBI. However, given the homogeneity of the plot areas pre-fire this question needs more research.

- The usefulness of decision trees to interpret MESMA cover fractions in terms of fire severity showed early promise in this study. However, with limited GeoCBI plots the true quality of the decision tree classification is uncertain. Given other recent studies successful use of decision trees for fire severity classification (Quintano *et al.* 2013), testing with more extensive ground validation data should be a research priority.

- The recent King Fire will have the same extensive pre- and post-fire hyperspectral data as the Rim Fire. The potential collection of a larger number of GeoCBI plots in the King Fire would provide a robust data set to further test many of the preliminary findings of this study.

Literature Cited

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