SENSITIVITY OF LANDSAT IMAGE-DERIVED BURN SEVERITY INDICES TO IMMEDIATE POST-FIRE EFFECTS

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INTRODUCTION

The USFS Remote Sensing Applications Center (RSAC) and the USGS Center for Earth Resources Observation and Science (EROS) produce Burned Area Reflectance Classification (BARC) maps as a rapid, preliminary indication of burn severity on large wildfire events. Currently the preferred burn severity index is the delta Normalized Burn Ratio (dNBR), which requires NBR values from both immediate post-fire and pre-fire Landsat images, the preferred satellite image source. The objective was to compare NBR, dNBR, and other indices with potential to indicate burn severity, using as the evaluation measure the correlation strength between the burn severity indices (BSI) and post-fire effects (PFE) measured on the ground.

METHODS

Fifty sites were established immediately post-fire across the full range of burn severities observed at four wildfires in western Montana, two in southern California, and two in interior Alaska. Sites consisted of nine plots systematically arranged to span a 130 m x 130 m area, with plots composed of fifteen 1 m x 1 m subplots sampling a 9 m x 9 m area. Surface cover fractions of soil, ash, litter, etc., and their degree of charring, were estimated ocularly at all subplots; soil water penetrability was measured in 22% of subplots; duff/litter depths and overstory canopy cover were measured at every plot; proportions of green/scorched/charred vegetation and seedling/sapling/shrub/tree mortality were estimated in one plot per site (Table 1). From Landsat images, NBR, NDVI, EVI, and 3 experimental NBR-like indices incorporating the thermal band (B6) (Holden et al. 2005) were generated, and delta indices calculated (Table 1). BSI pixel values were extracted at the subplot locations; then both the PFE and BSI data were aggregated at the plot scale, to account for both fine-scale variability in the field and pixel variability in the image. Pearson correlations between the 32 PFE and 13 BSI were then calculated.

RESULTS AND DISCUSSION

Among the 13 BSI considered, NBR produced the highest correlations to PFE across all fifty sample sites. In Montana mixed conifer forest, BSI calculated from solely the immediate post-fire imagery correlated better with PFE than did the delta BSI, while in California chaparral the delta BSI performed better. In Alaska boreal forest, the differences between BSI were negligible (Figure 1). Given the similar results for the highly correlated NBR, NDVI and EVI, the higher vulnerability of NDVI and EVI to smoke and haze effects argues for choosing NBR. The three experimental NBRT indices showed no improvement over NBR in any of the three ecosystems sampled. The current preference of dNBR over NBR for BARC mapping is likely more advantageous for assessments of extended PFE than this analysis suggests, but only immediate PFE were considered in this analysis.

Table 1. A) Immediate Post-Fire Effects (PFE) measured in the field; B) Burn Severity Indices (BSI) derived from Landsat imagery.

A) Field Data-Derived Post-Fire Effects (PFE)

Overstory
- overstory canopy cover (%)
- green tree crown (%)
- scorched tree crown (%)
- charred tree crown (%)
- dead trees (%)

Understory
- dead high shrubs (%)
- dead saplings (%)
- dead seedlings (%)
- green understory cover (%)
- scorched understory cover (%)
- charred understory cover (%)

Surface
- new litter fractional cover (%)
- old litter fractional cover (%)
- ash fractional cover (%)
- soil fractional cover (%)
- rock fractional cover (%)
- uncharred organic fractional cover (%)
- charred organic fractional cover (%)
- total organic fractional cover (%)
- uncharred inorganic fractional cover (%)
- charred inorganic fractional cover (%)
- total inorganic fractional cover (%)
- total green fractional cover (%)
- total uncharred fractional cover (%)
- total charred fractional cover (%)

Subsurface
- new litter depth (mm)
- old litter depth (mm)
- duff depth (mm)
- duff moisture (%)
- mini-disk infiltrometer rate (ml/min)
- mini-disk infiltrometer time (s)
- water drop penetration time (s)

B) Landsat Data-Derived Burn Severity Indices (BSI)

Normalized Burn Ratio (NBR)
$(B4 - B7) / (B4 + B7)$

delta Normalized Burn Ratio (dNBR)
pre-fire NBR - post-fire NBR

Relative delta Normalized Burn Ratio (RdNBR)
(pre-fireNBR - post-fire NBR) / sqrt(abs(pre-fire NBR))

Normalized Difference Vegetation Index (NDVI)
$(B4 - B3) / (B4 + B3)$

delta Normalized Difference Vegetation Index (dNDVI)
pre-fire NDVI - post-fire NDVI

Enhanced Vegetation Index (EVI)
$2.5 * (B4 - B3) / (B4 + 6.0 * B3 - 7.5 * B1 + 1)$

delta Enhanced Vegetation Index (dEVI)
prefire EVI - post-fire EVI

Normalized Burn Ratio-Thermal 1 (NBRT1)
$(B4 - B7 * (B6/1000)) / (B4 + B7 * (B6/1000))$

delta Normalized Burn Ratio-Thermal 1 (dNBRT1)
pre-fire NBRT1 - post-fire NBRT1

Normalized Burn Ratio-Thermal 2 (NBRT2)
$(B4 / (B6/1000) - B7) / (B4 / (B6/1000) + B7)$

delta Normalized Burn Ratio-Thermal 2 (dNBRT2)
pre-fire NBRT2 - post-fire NBRT2

Normalized Burn Ratio-Thermal 3 (NBRT3)
$(B4 - (B6/1000) - B7) / (B4 - (B6/1000) + B7)$

delta Normalized Burn Ratio-Thermal 3 (dNBRT3)
pre-fire NBRT3 - post-fire NBRT3

SUMMARY AND CONCLUSIONS

These burn severity data spanned a huge range of western North American ecosystems where wildfires commonly occur, and could be considered broadly representative at a continental scale. These results suggest that RSAC or EROS should continue to use NBR and dNBR for operational production of BARC maps from Landsat imagery.

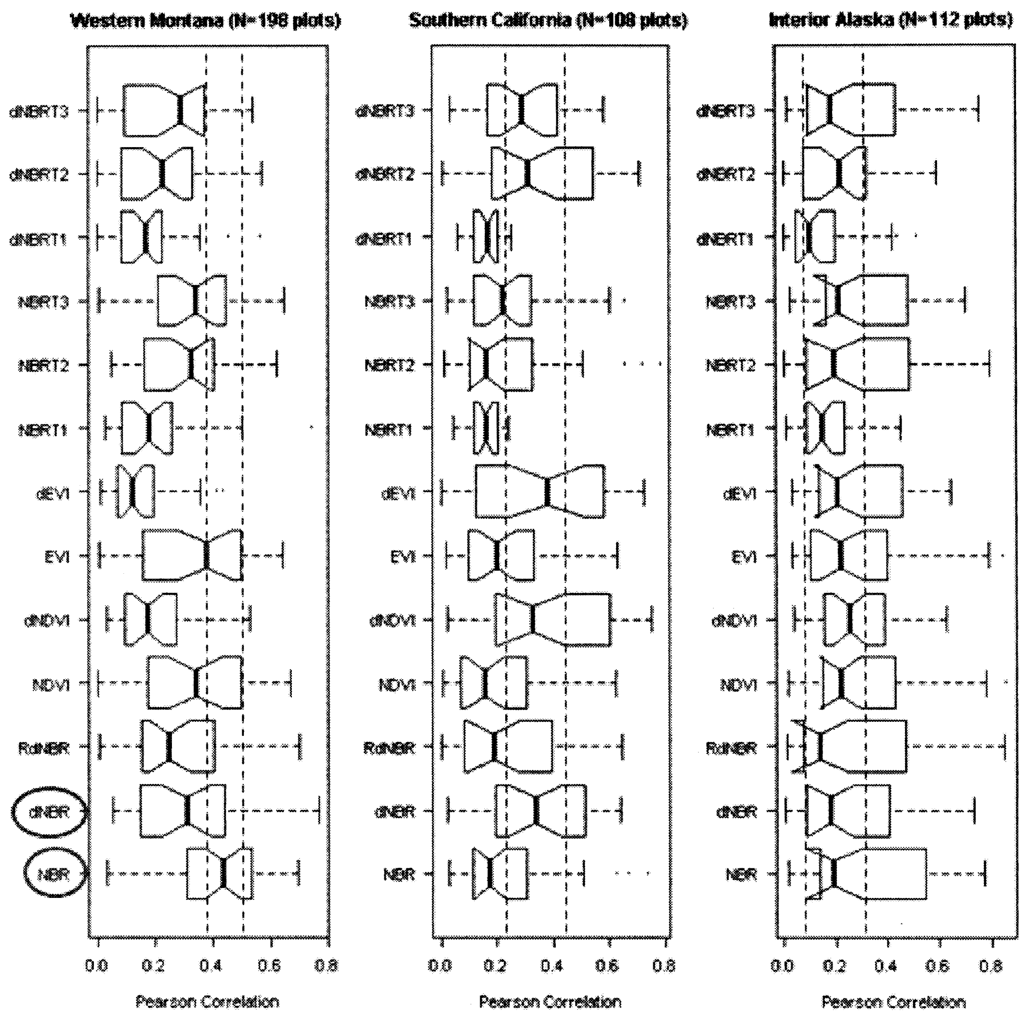

Figure 1. Boxplots of Pearson correlations (absolute values) between 13 BSI (plotted on y axes) and 32 PFE (Table 1). Colored lines indicate boxplot notch width for the better of the dNBR (green) or NBR (red) indices currently used for preliminary BARC maps. Non-overlapping notches between boxplots suggest that the medians significantly differ (Chambers et al. 1983).

LITERATURE CITED

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