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"MEASURING AND REMOTE SENSING OF BURN SEVERITY"

Carl H. Key, USGS Northern Rocky Mountain Science Center Nate C. Benson, USNPS Glacier National Park²



THE COMPOSITE BURN INDEX (CBI): FIELD RATING OF BURN SEVERITY

UNDERSTORY

OVERSTORY

<u>Mean = 1.62</u> Std. Dev = 1.01 N = 88

Mean = 1.70 Std. Dev = .74 N = 88

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USGS Glacier Field Station Present Address: c/o Glacier National Park **Everglades National Park** West Glacier, MT 59936 Fire Management Office 40001 State Rd 9336 carl_key@usgs.gov Homestead, FL 33034-6733 nate_benson@nps.gov

ABSTRACT

The Composite Burn Index (CBI): Objectives to correlate remote sensing data with observed fire effects require definition of burn severity, and a sampling strategy that matches recorded field characteristics to sensor capabilities. The Composite Burn Index (CBI) is designed to define burn severity ecologically, and measure ground effects which collectively provide a signal detected at moderate resolution by the Landsat Thematic Mapper. Average conditions of the community are evaluated ocularly by vegetative strata within relatively large heterogeneous plots. Attributes are rated by criteria which correspond to identified burn levels along a gradient from unburned to extremely burned conditions. The criteria scale considers not only specific physical properties, but also the distribution of traits within plots. Attribute scores then are segregated hierarchically by strata and averaged into understory, overstory, and overall composite ratings. Sampling confirms variable burn responses by strata consistent with observations over the range of severity, suggesting the criteria and rating scale are appropriate. Ratings which incorporate all strata seem to improve the overall measure of severity, and emphasize the importance of considering a broad range of factors when summarizing burns. We suggest the CBI is transferrable and a basis for studying or comparing burns across broad geographic regions. The strategy facilitates direct correlation of burn severity to radiometric response variables and may be used in modeling other environmental factors, such as fuel loading or erosion potential. At the same time, the methodology could be used in the absence of remote sensing data to describe and evaluate localized burn sites for a variety of purposes.

HATICHAL DARK SERVICE

The Normalized Burn Ratio (NBR): We used the CBI (above) to test performance of radiometric measures as estimators of burn severity. Two 1994 fires occurring at Glacier National Park, Montana, were investigated. Indices incorporated band ratios and multitemporal differencing derived from the Landsat Thematic Mapper, including: 1) post-fire band 7 reflectance; 2) pre- and post-fire differenced band 7 reflectance; 3) differenced Normalized Difference Vegetation Index (NDVI), and 4) differenced Normalized Burn Ratio (NBR), a new index formulated from TM band 7 and band 4 reflectance. Seasonal effects also were tested, with indices obtained from spring and late summer data, for a total of eight models. Evaluation of performance considered amplitude of index response, direct correlation to fieldrated burn severity, and visual characteristics of derived images. NBR differenced from early in the growing season was judged the most effective measure of burn severity. Greater amplitude of response and correlation to field-rated burn severity led to better contrast, broader range of severity levels, and sharper delineation of burn perimeters. NDVI differenced late in the growing season exhibited the poorest resolution of burn severity overall. In general, results were improved for all indices when derived early in the growing season. Seasonal differences, however, were influenced by phenology and not strictly by date. Spring scenes performed best at low elevations, while late summer results were stronger at high elevations, where snow melt and plant growth was delayed by at least two months. To facilitate assessment of burn conditions through mapping and summary tabulation, differenced NBR was partitioned into 7 ordinal levels (including meadow, forest, and unburned classes) which exhibited strong relationships to burn severity rated on field plots. Advantages differenced NBR include: 1) a standard, transferable measure with reduced influence from image- or observer-dependent qualities; 2) utility on large, remote burns and potential to compare multiple burns regionally or nationally; 3) direct correlation to fieldestimated fire effects and other quantitative environmental variables; and 4) flexibility to apply the measure as a continuous or discrete variable in modeling, research and management.

PLOT #: Observer:	PLOT SIZE:	DATE: Time Since Fire:	FIRE:	UTM E: GPS Paramet		UTM N: ters:		
		SCORE POS	Γ-FIRE EF	FECTS				
CRITER	RIA							
	NO EFFECT	LOW 0.5 1.0	1.5	MODERATE	2.5	HIGH 3.0		
Substrate: litter duff fuels <7.6 cm fuels >7.6 cm Δ soil, color/c	unchanged unchanged unchanged unchanged unchanged cover unchanged	50% loss light char 50% loss 5% loss, blac 10% change	kened	80% loss 50% loss, deep char 80% loss 15% loss, deep char 40% change		consumed consumed consumed >30% loss, deep char >80% change	11	
		ES					ξ	
Herb/Low S	Shrub:						DE	
Fire Moss, co regeneration new serals (h ∆ richness/co	ver none 100% erbs) none over unchanged	trace, spotty 90% Iow little change	moderate	moderate 50% high moderate change	high <20%	low none low to none high change	RSTOR	
Tall Shrub/	Sapling: 1-5 m h	igh						
% consumed re-gen shrub/ new serals (p	none trees 100% ico) none	10% 80% Iow		50% 30% moderate	<10% high	>90% none low to none		
Ntermediat % green % brown (sco % black (torcl _ ch <u>ar height</u>	e frees: approxi 100% orch) none h) none 	10-20 CM al 80% 5-20%, or <10 5-20% 1. <u>5 m</u>	ameter and y	5-20 m nign 40% 40-80%, or >50' 60% 2.75 m	<10% <20% >85%	none none branching consumed >5 <u>m</u> _	0	
Optional, other % girdled (bo	r mortality indicators le/root) none	10%		50%		>75%	VERS	
Big Trees:	trees larger than	intermediate trees		E0%	~10%	2020	70	
% brown (sco	orch) none	5-10%, or <15	5'	30-70%, or >80'	<10%	none		
% black (torcl char height	h) none none	5-10% 1.75'		50% 4 m	>85%	branching consumed >7 m		
Optional, other % girdled (bo	r mortality indicators le/root) none	 10%		 50%		>75%	Ш	
PLANT COMMUNITY / NOTES:			Count Rated Criteria Only: COMPOSITE					
		STR Sub Lov Tall Inte Big	ATA ostrate v Shrub/Herb I Shrub/Saplir ermediate Tree Trees	Score Sum	N Crite	eria Average		
Time-dependen	It tree factors:		ERSTORY RSTORY					
Total % mort	ality	тоти	AL PLOT					

BURN SEVERITY RATING MATRIX

Increase cover of exposed mineral soil, and change from native color, general lightening with loss of organics. At high end up to 10-15% reddisl b. Amount of regrowth from plants that burned but survive from living roots and stems, relative to estimated pre-fire vegetation plot-wide. . Potential dominance within a 4-year time span, averaged for plot. Frequency may be more recognizable at first with cover increasing over time.



We evaluated the rating system on 88 field plots, representing a broad range of fire effects. The CBI quantified severity independently in 5 strata, and at aggregate levels of understory, overstory, and total plot. CBI captured properties expected from fire behavior, as observed in the field. Strata scores were all significantly correlated, but those in close spatial proximity had highest associations (top right). Strata farthest apart were most variant (top center). Where dissimilarities occurred, they were greatest at lower burn severities. Differential effects in under- and over-story (left and below) reflected heating thresholds, e.g. overstory moved quickly to high severity once fire reached the canopy. Total plot scores (top left) integrated variations among strata and seemed best suited for remote sensing applications. Rating criteria can be tailored to any ecosystem, to compare fires at multiple levels in a standard way for broad-scale monitoring.





ight charring, up to moderate consumption of downed fuels. Regenerated forbs and grass dominate understory. Shrubs and saplings show little mortality. Overstory not scorched or blackened, and tree charring remains < 2 m.

Understory - 1.95 Overstory - 2.25 Total Plot - 2.06

Deep char, largely consumed small fuels. Increased densities of new serals (fireweed, lodgepole pine), but some pre-fire herbs and shrubs persist. Most tree crowns blackened or largely scorched, a few green crowns remain.

Understory - 2.45 Overstory - 2.92 Total Plot - 2.63

Major portions of large downed fuels consumed, substantial amounts of exposed mineral soil. Prefire herbs and shrubs essentially absent, low-

e. Crown foliage condition of whole plot, relative to estimated pre-fire crown volume. Except, char height is the average median height on tree boles Percent of trees on plot burned through the bark to a degree of 50% or more around circumference of lower boles or buttress roots

This form identifies criteria used to rate attributes in the northern U.S. Rocky Mountains. Though intended to be generic, attributes and criteria may differ slightly in other regions. Scores reference average conditions within relatively large plots (20-30 m diameter). Scores are summed and averaged by strata, understory/overstory, and overall to yield composite indices, lower right.

0.0-0.5 1.0-1.5 2.0-2.5 0.5-1.0 1.5-2.0 2.5-3.0	.3 -		· - · · · · · · · · · · · · · · · · · ·	-¥	
COMPOSITE BURN INDEX	0.0	Q3.082.0089.00	\$\$\$^7127789589993750579970747878989 \$\$\$71750709707687070570797070707070707070707070707070707	\$\$~\$	ૣ ૾ૺૡ૿ૢ૱ૺૡૻ૽ૡૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢૢ

SAMPLE N=88 (Sorted by Total Plot Score)

We compared all radiometric and seasonal measures to

the Composite Burn Index (CBI) sampled from 88 plots,

described above. Since all measures were ratio-level

variables, testing was done by regression and direct

advantage over other methods that rely on categorical or

RIGHT -- The NBR Spring difference had greatest dynamic

range of values within burns. It thus provided highest contrast between burn severity levels, as well as best

distinction between burned and unburned areas, without

further scaling of data. For all measures, Spring results

measures, NBR had greatest correlation to field-rated CBI

BELOW -- As a continuum, NBR difference was the best

predictor of burn severity. However, it can be partitioned

into severity levels or classes, on statistical grounds, if

depending on the application. Here we identify five levels,

including unburned, with statistical characteristics shown,

desired. Number and range of classes is flexible

BOTTOM -- Selected imagery compares indices and seasons as continuous measures of burn severity. At

severity levels, plus meadow burns. An additional

and reliability of delineating burn perimeters.

bottom right, differenced NBR is partitioned into the 5

advantage of this method is demonstrated by the ease

performed better than Late-Summer results. Across

evaluation of goodness-of-fit. This represented an

ordinal data for verification.

regardless of season.

below right.



THE NORMALIZED BURN RATIO (NBR): A LANDSAT TM RADIOMETRIC MEASURE OF BURN SEVERITY

STUDY AREA





What effect did they have?



Enlargements of the 1995 classification (left) showing Starvation and Adai

Multi-temporal image differencing provides a general strategy to quantify change from one time to the next. The question is, however, what radiometric value and what time of year offers best discrimination of burn characteristics.

Four Landsat TM scenes were processed representing Spring and Late-Summer dates, before and after fire. This raw dataset was standardized, using a number of transformations to permit direct radiometric comparisons between scenes: 1) radiance; 2) rectification; 3) reflectance; and 4) date-todate normalization of atmospheric transmittance.

From a random sample of pixels inside the burns, TM bands 4 and 7 exhibited the greatest reflectance change in response to fire. We hypothesized that a ratio of those bands would be most discriminating for burn effects, and constructed the Normalized Burn Ratio from their transformed reflectance (R) values:

$$NBR = \frac{R4}{R4}$$

R7 increased with fire, while R4 decreased, and those trends were accentuated in the normalized ratio. The NBR was calculated for each of the four TM scene dates. Then, for both Spring and Late-Summer pairs, the NBR image after fire was subtracted from the NBR image before fire. This yielded two seasonal models of NBR change, with values increasing positively as burn severity increased.

For comparison, we constructed models of three other radiometric measures of burn severity reported in the literature: 1) post-fire R7; 2) before-and-after fire R7 difference; and 3) the NDVI difference. As above, these were derived independently for both Spring and Late-Summer to evaluate seasonal effects.

Note: NDVI is the Normalized Difference Vegetation Index similarly constructed as the NBR, but from TM bands 4 and 3. All calculations were done with floating point math, and results were scaled by 1000 to store positive and negative values in 32-bit images, retaining at least 4 significant digits.

> PLOT CBI (Field Sampled Composite Burn Index) LANDSAT TM Radiometric Indices NBR Spring Difference NDVI Spring Difference * TM Band 7 Spring Post-Fire TM Band 7 Spring Difference





MONTANA, USA

Landscape of northwest Glacier National Park viewed September 1, 1995 approximately one year after the Starvation and Adair Ridge Fires. The 1988 GLACIER NATIONAL Red Bench Fire also is clearly evident (center). The image is a multi-spectral PARK classification of Landsat TM bands 3, 4, and 5, with classes colored to simulate infrared photography. Increasingly, remote sensing technologies are required by the National Park Service to assess and monitor wildfires, where fire size, remoteness, and rugged terrain make alternative methods impractical.

Ridge Burns of 1994. New satellite remote sensing techniques are needed to consistently distinguish burned from unburned areas, to separate recent from older burns, and to quantify severity of effects within the burns. We developed the Normalized Burn Ratio (NBR) to improve upon previous methods which typically did not fully resolve one or more of those features.



PLOTS GROUPED BY SEVERITY CLASS AND SORTED BY CBI SCORE

Images of radiometric indices, below, show near-zero values as medium gray (i.e. no change); lighter is increasingly positive, darker is increasingly negative.

Spring NDVI difference and Late-Summer NBR difference, below, were close in performance to the NBR Spring difference. Statistically, and by image contrast (i.e. range of values), however, both models were less robust and reliable at distinguishing severity levels. A) small area of burning remains active on 8/13/94.



LATE-SUMMER NBR DIFFERENCE ADAIR Sept 1, 1995) - (Aug 13, 1994)

Both models, below, were used to quantify fire effects on the 1994 Glacier Park burns. Perimeters were readily interpreted and digitized "on screen" in a GIS.



As needed, severity classes can be mapped to simplify interpretations. Such models provide useful ways to spatially assess impacts (good or bad) and target management.



Are you interested in habitat enhancement, erosion potential, future fire breaks, weed invasion, biodiversity, how wildfires burn, or just a good place to find woodpeckers?









Seasonality of results is really a phenological effect. Where fires burn up into high elevation, as in the Starvation Fire, below, combined Spring and Summer data optimizes measured burn response in low and high zones, and can mitigate irrelevant effects, such as, B) areas snow covered in both spring scenes; or C) clouds in the 5/28/95 scene.





