Remote sensing for assessing fire severity and combustion completeness in SoCal and AZ

Sander Veraverbeke, S. Hook, G. Hulley, S. Harris (JPL)

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What is ‘severity’ and why measure it?

SEVERITY: degree of environmental change caused by a fire

Fire Ecology, Vol. 2, No. 2, 2006

ECOLOGICAL AND SAMPLING CONSTRAINTS ON DEFINING LANDSCAPE FIRE SEVERITY

Carl H. Key

Usefulness of fire severity data?

1) Planning of post-fire management (erosion control, rehabilitation)
2) Improving emission estimates

OPERATIONAL WAY-TO-GO?

Emission = Area X Mass X Combustion factor X Emission factor

Could be refined by fire severity data

Remote Sensing of Environment 114 (2010) 1535–1545

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

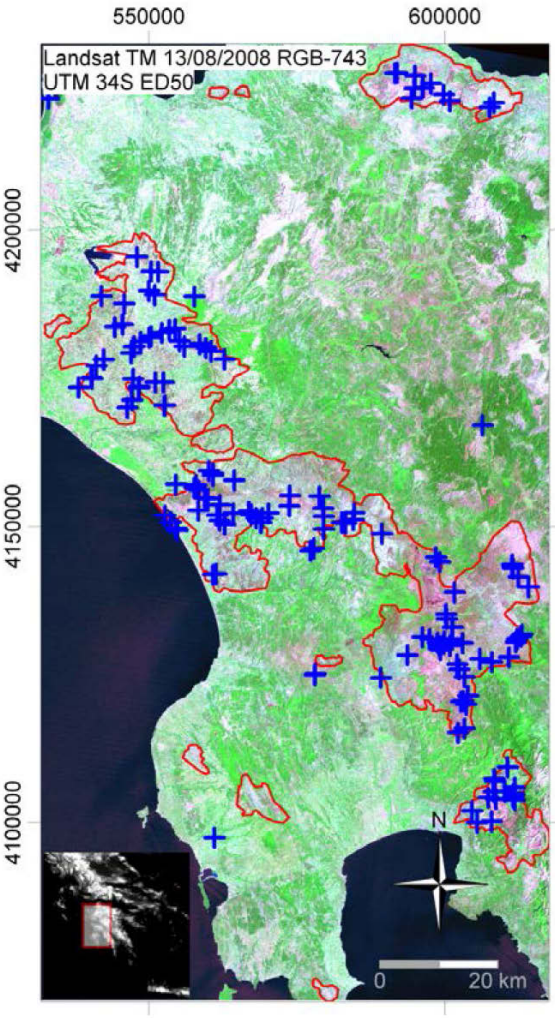
ELSEVIER

Mapping burn severity and burning efficiency in California using simulation models and Landsat imagery

Angela De Santis [a,*], Gregory P. Asner [b], Patrick J. Vaughan [c], David E. Knapp [b]

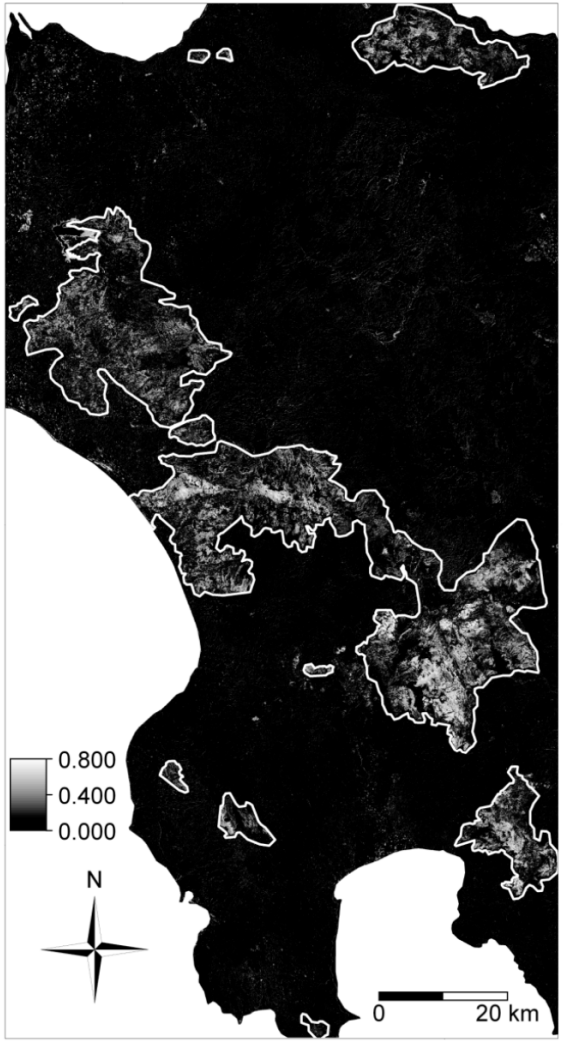
RS solution for fire severity so far?

the Normalized Burn Ratio (NBR)

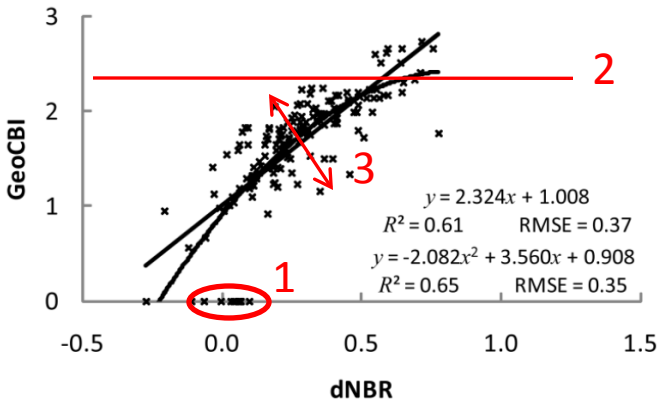


$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

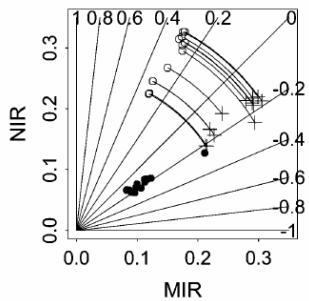
$$dNBR = NBR_{pre} - NBR_{post}$$



Criticism on the (d)NBR



1) Insensitivity to unburned pixels
2) Saturation at GeoCBI > 2.5
3) High dispersion of point cloud



Sub-optimal index design

IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 3, NO. 1, JANUARY 2006

Remote Sensing of Fire Severity: Assessing the Performance of the Normalized Burn Ratio

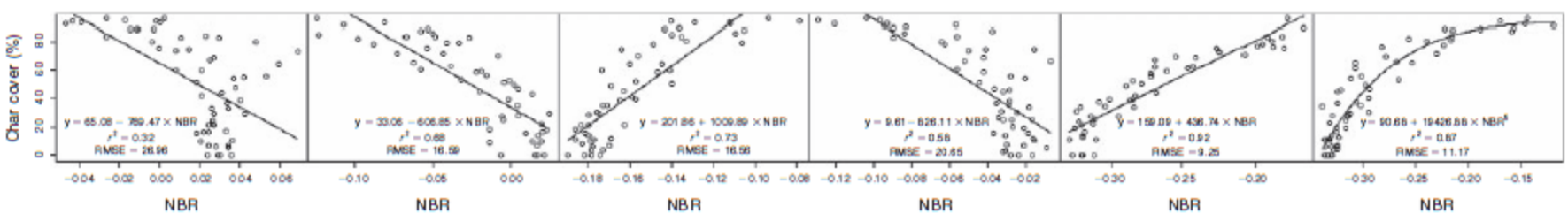
David P. Roy, Luigi Boschetti, and Simon N. Trigg

Research Note
CSIRO PUBLISHING
International Journal of Wildland Fire 2010, 19, 976–983
www.publish.csiro.au/journals/ijwf

Spectral analysis of charcoal on soils: implications for wildland fire severity mapping methods

Alistair M. S. Smith[A,C], Jan U. H. Eitel[A] and Andrew T. Hudak[B]

Sensitive to soil brightness variations



Criticism on the (d)NBR (part 2)

Sensitive to illumination effects and phenological mismatch

CSIRO PUBLISHING
www.publish.csiro.au/journals/ijwf
International Journal of Wildland Fire **2008**, *17*, 527–534

Seasonal and topographic effects on estimating fire severity from Landsat TM/ETM+ data

David L. Verbyla[A,C], *Eric S. Kasischke*[B] *and Elizabeth E. Hoy*[B]

International Journal of Applied Earth Observation and Geoinformation 12 (2010) 60–70
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Illumination effects on the differenced Normalized Burn Ratio's optimality for assessing fire severity

S. Veraverbeke [a,*], W.W. Verstraeten [b], S. Lhermitte [c], R. Goossens [a]

The dNBR does not account for pre-fire landscape heterogeneity

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Remote Sensing of Environment 109 (2007) 66–80
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Quantifying burn severity in a heterogeneous landscape with a relative version of the delta Normalized Burn Ratio (dNBR)

Jay D. Miller [a,*], Andrea E. Thode [b]

Results might be site-specific

What is the physical meaning of a (d)NBR value??

Criticism on the (d)NBR (part 2)

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Research overview

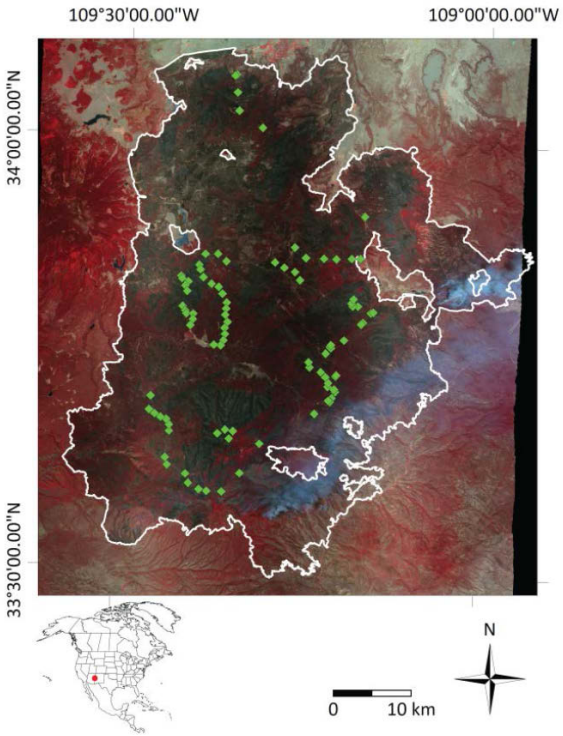
- An alternative spectral index for rapid fire severity assessments

- Evaluating spectral indices and SMA for assessing fire severity

- Synergizing VSWIR and MTIR data for post-fire assessments

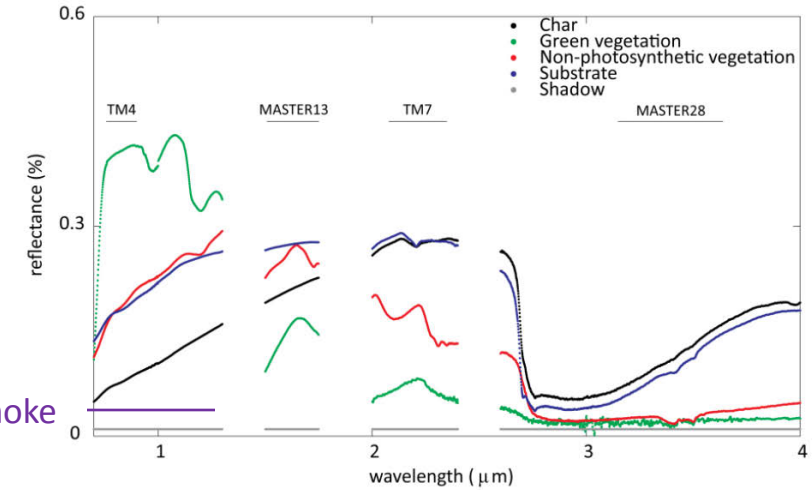
- Estimating combustion completeness and carbon emissions by combining remote sensing and modeling

An alternative spectral index for rapid fire severity assessments



MASTER data over large 2011 Wallow fire, AZ

Spectroscopy data



Impeded by smoke

Spectral indices

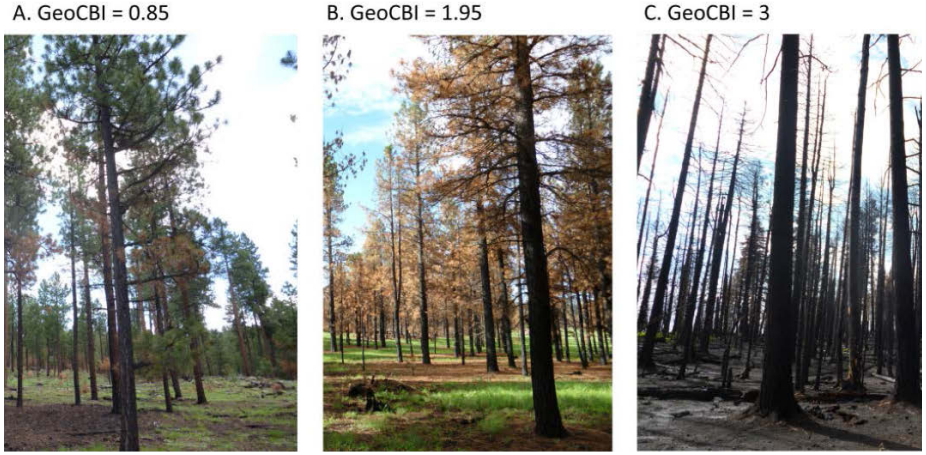
$$NBR = \frac{NIR - LSWIR}{NIR + LSWIR}$$

$$dNBR = NBR_{pre} - NBR_{post}$$

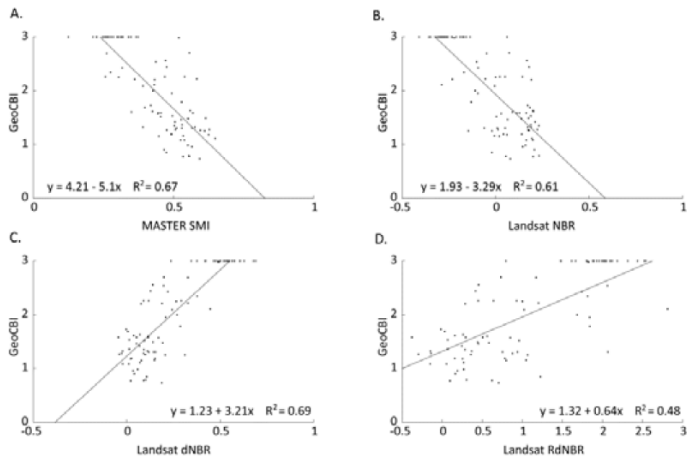
$$RdNBR = \frac{dNBR}{\sqrt{abs(NBR_{pre})}}$$

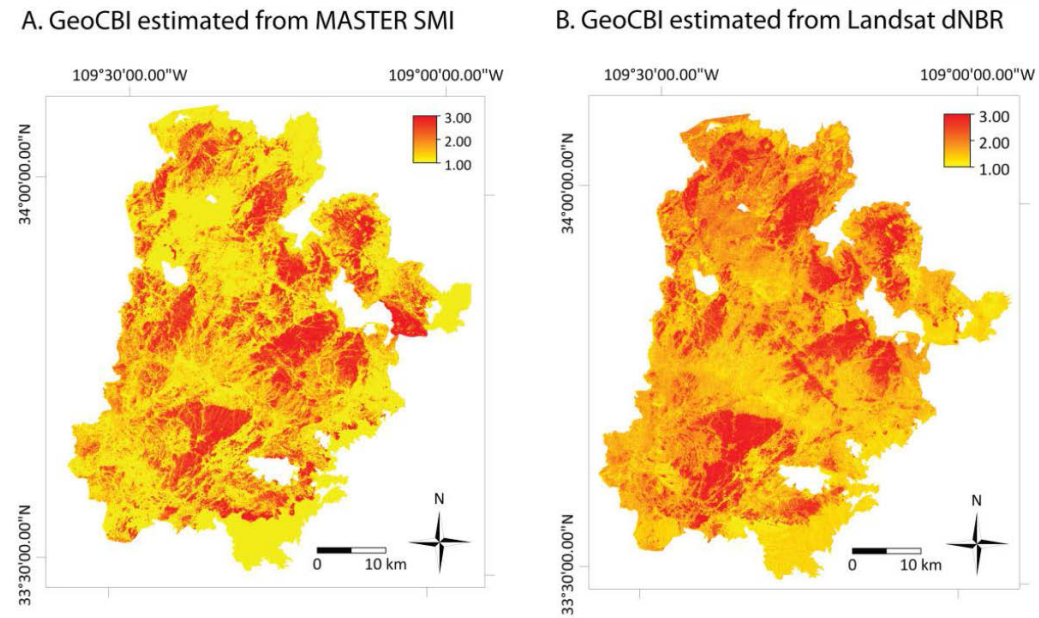
$$SMI = \frac{SSWIR - MIR}{SSWIR + MIR}$$

Fire severity data



An alternative spectral index for rapid fire severity assessments





	Training			Validation		
SI	a	b	R^2	a	b	R^2
NBR	1.96 (0.08)	-3.37 (0.14)	0.59 (0.05)	-0.02 (0.28)	0.98 (0.08)	0.60 (0.06)
dNBR	1.24 (0.07)	3.24 (0.21)	0.68 (0.04)	-0.13 (0.26)	1.06 (0.09)	0.71 (0.05)
RdNBR	1.34 (0.07)	0.64 (0.12)	0.42 (0.07)	-0.10 (0.30)	1.02 (0.20)	0.51 (0.07)
SMI	4.22 (0.17)	-5.12 (0.46)	0.65 (0.05)	-0.08 (0.44)	1.04 (0.15)	0.69 (0.06)

SMI has similar performance as dNBR, but is mono-temporal and not impeded by smoke

Remote Sensing of Environment xxx (2012) xxx–xxx

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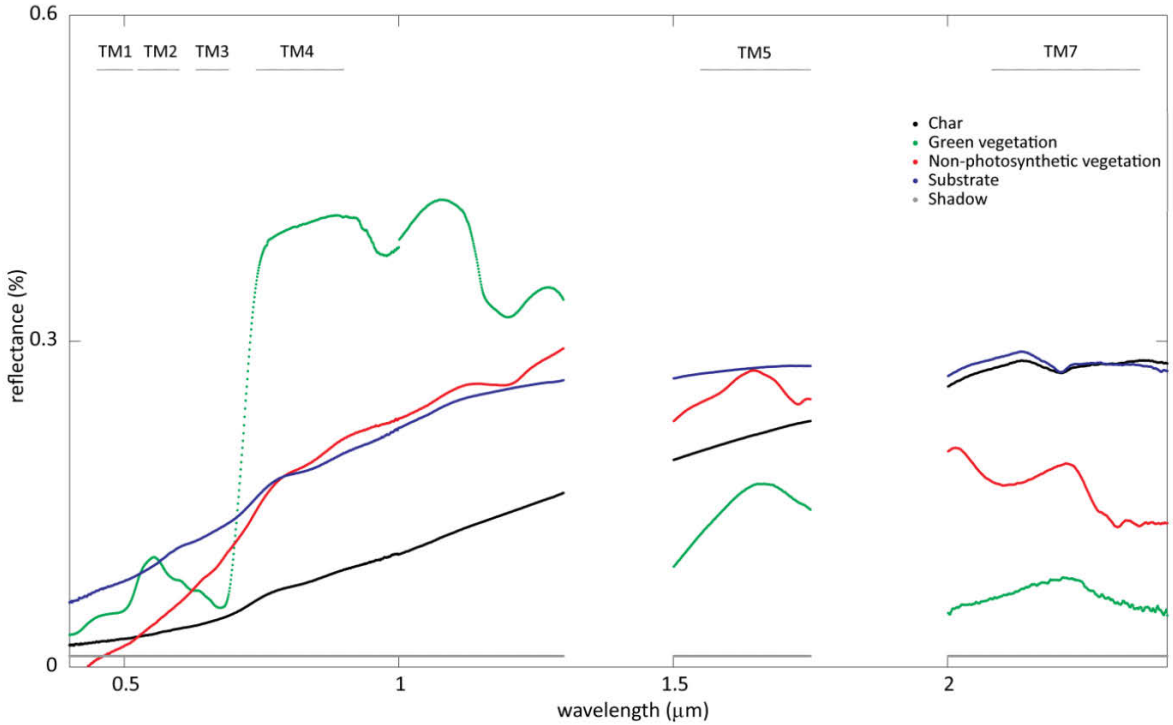
An alternative spectral index for rapid fire severity assessments

S. Veraverbeke*, S. Hook, G. Hulley

Evaluating spectral indices and SMA for assessing fire severity

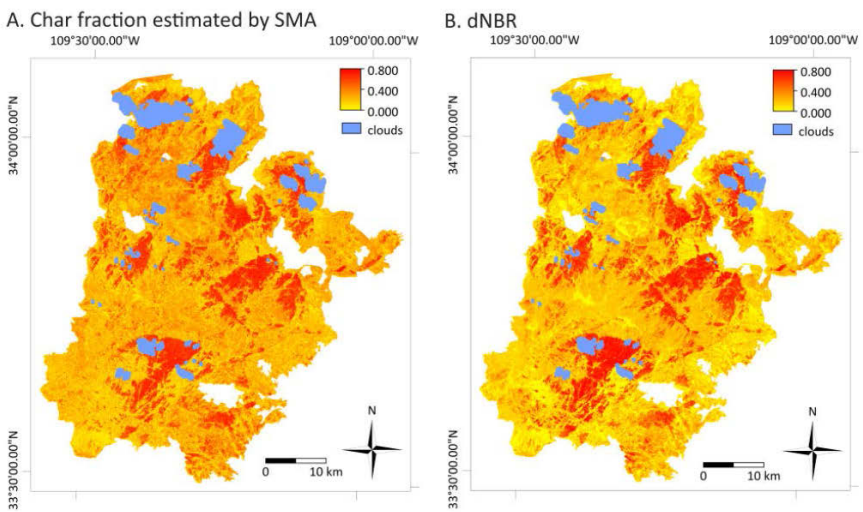
Landsat imagery over large 2011 Wallow fire, AZ

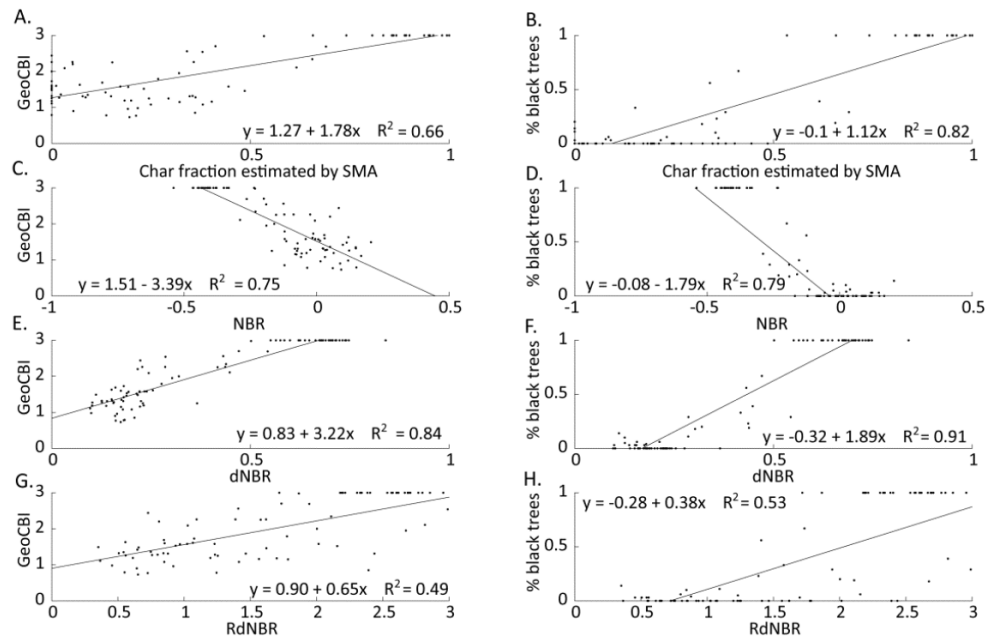
Spectroscopy data



Fire severity data

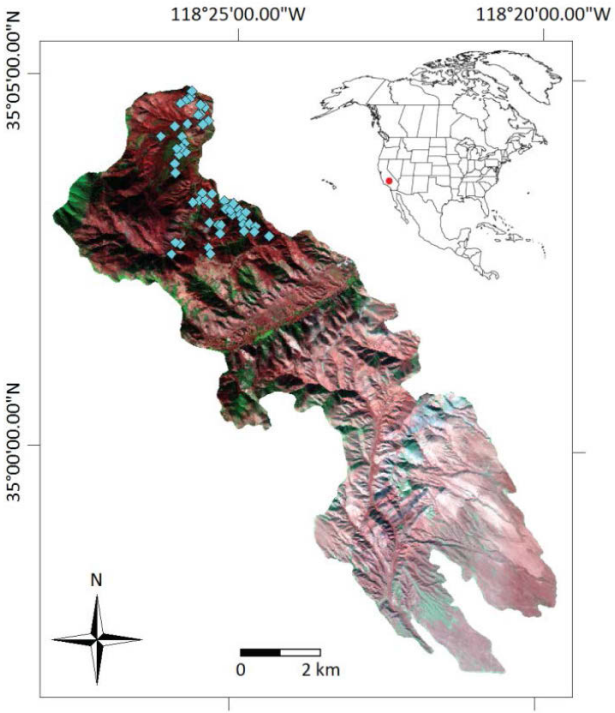
Evaluating spectral indices and SMA for assessing fire severity





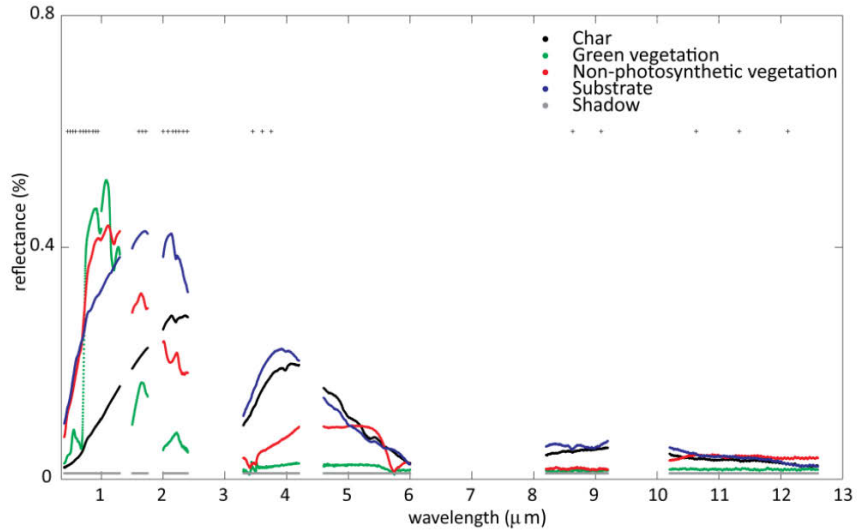
dNBR performs slightly better than the char fraction estimated by SMA, but the SMA provides a more 'useful' quantitative assessment

Synergizing VSWIR and MTIR data for post-fire assessments



MASTER data over Canyon fire, CA

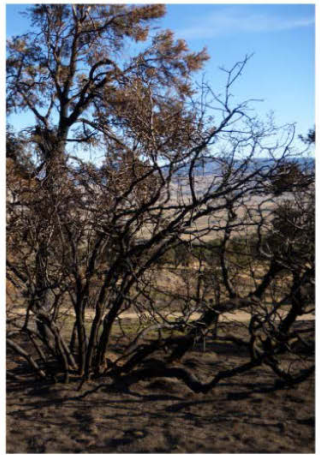
Spectroscopy data



Fire severity data

A. GeoCBI = 1.5

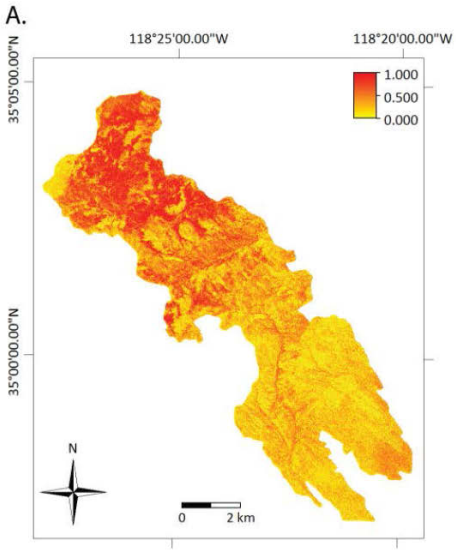
B. GeoCBI = 2.6

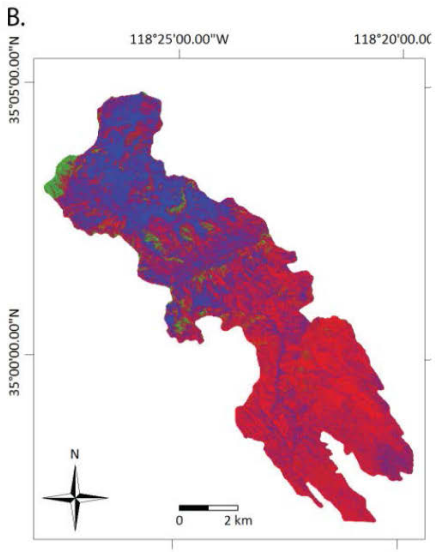


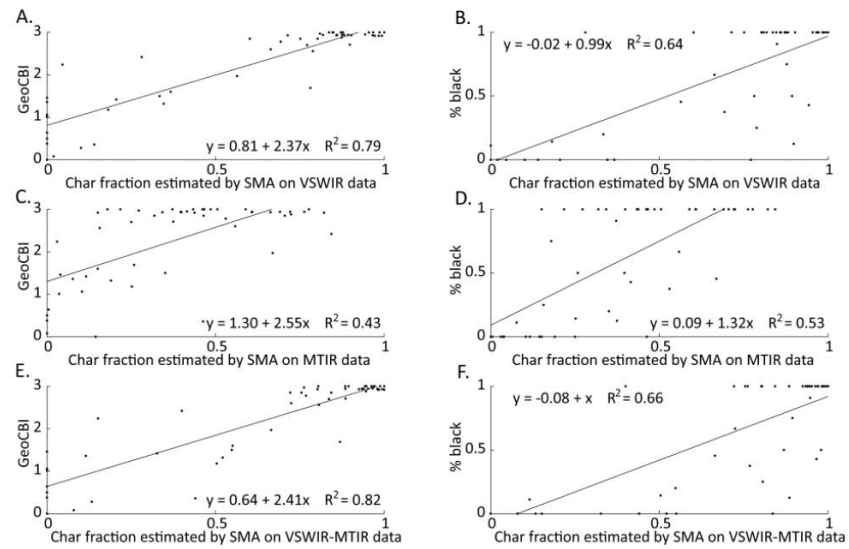
C. GeoCBI = 3

Synergizing VSWIR and MTIR data for post-fire assessments

Spectral region	Char			GV			NPV			Substrate		
	R^2	a	b	R^2	a	b	R^2	a	b	R^2	a	b
VSWIR	0.88	0.00	0.98	0.91	0.01	0.99	0.83	0.01	0.94	0.87	0.00	1.01
MTIR	0.31	0.03	0.86	0.22	0.01	0.92	0.34	0.07	0.80	0.57	0.00	0.94
VSWIR-MTIR	0.93	0.00	1.01	0.92	0.01	0.98	0.90	0.01	0.97	0.94	0.00	1.02

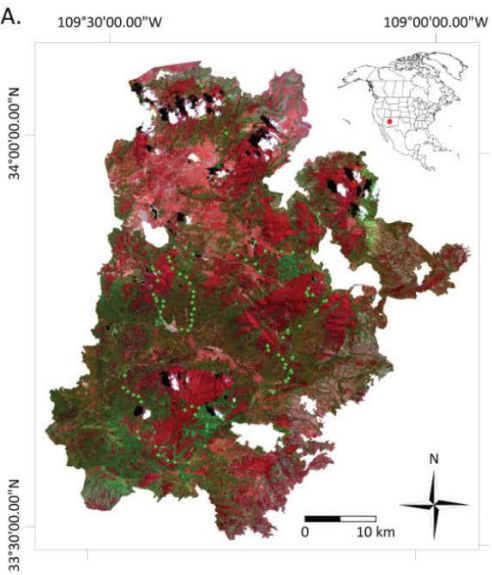


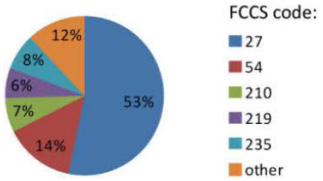


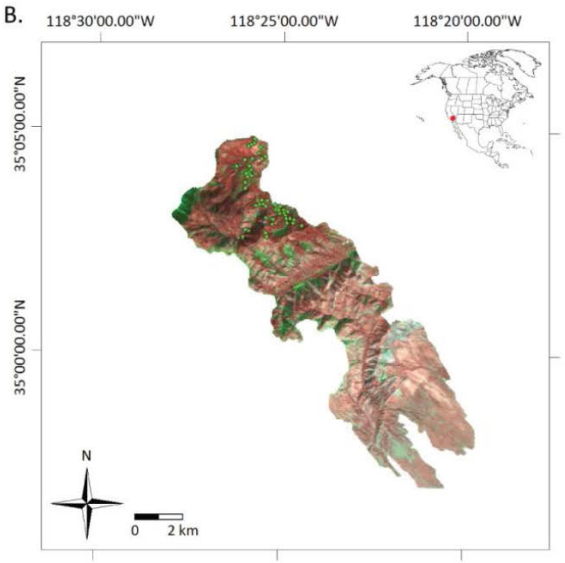


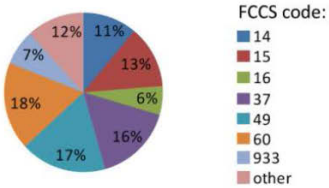
Discrimination between ground covers in post-fire environments is better with VSWIR data than with MTIR data, but their synergy yields the best results

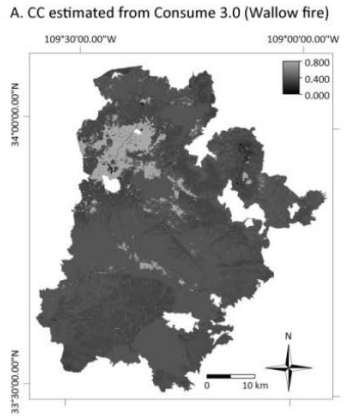
Estimating combustion completeness and carbon emissions by combining remote sensing and modeling

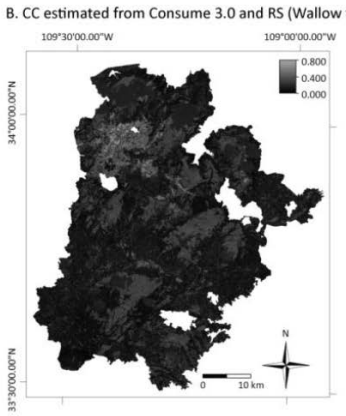


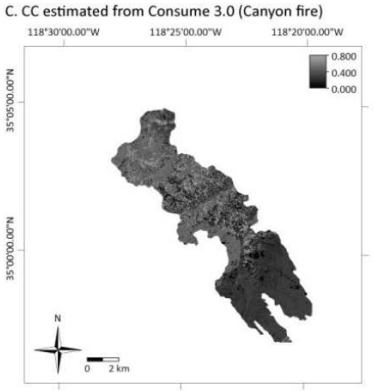


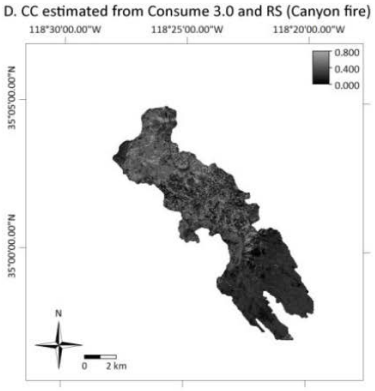






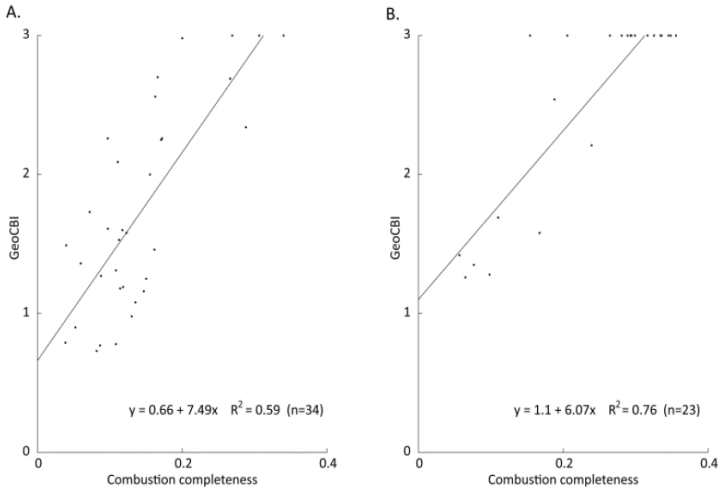






Estimating combustion completeness and carbon emissions by combining remote sensing and modeling

Fire	FCCS Code	n	$GeoCBI = a + b \times CC$			$\% black = a + b \times CC$		
			R^2	a	b	R^2	a	b
Wallow	27	34	0.59	0.66	7.49	0.57	-0.28	3.38
Wallow	54	23	0.76	1.10	6.07	0.69	-0.23	3.81
Wallow	219	10	0.41	1.55	3.82	0.82	-0.23	3.51
Wallow	235	5	0.89	0.77	7.07	0.87	-0.33	4.17
Canyon	14	8	0.72	-3.99	15.25	0.50	-1.29	4.41
Canyon	16	20	0.57	-0.22	8.22	0.49	-0.54	3.84
Canyon	37	9	0.74	-0.21	6.54	0.37	-0.53	2.83



Fire	Burned area (ha)	CC estimation methodology	Total C emission (Tg)	Area normalized C emission (kg/m^2)	% carbon emitted relative to Consume 3.0 approach
Wallow	218 000	Consume 3.0	3.44	1.57	1
Wallow	218 000	Consume 3.0 and RS	1.52	0.70	0.45
Canyon	5900	Consume 3.0	0.12	2.02	1
Canyon	5900	Consume 3.0 and RS	0.09	1.60	0.73

Combined use of RS and modeling has potential for estimating CC

Significant differences in emission estimates whether or not within-burn heterogeneity is incorporated

Related publications

Veraverbeke, S., Hook, S. (2012). *Evaluating spectral indices and spectral mixture analysis for assessing fire severity and adjusting burning efficiency using Landsat imagery.* International Journal of Wildland Fire, in review.

Veraverbeke, S., Hook, S. & Hulley, G. (2012). *An alternative spectral index for rapid fire severity assessments.* Remote Sensing of Environment, in press.

Harris, S., Veraverbeke, S., & Hook, S. (2011). *Evaluating spectral indices for assessing fire severity in chaparral ecosystems (southern California) using MODIS/ASTER (MASTER) airborne simulator data*. Remote Sensing, 3, 2403-2419.

Veraverbeke, S., Harris, S. & Hook, S. (2011). *Evaluating spectral indices for burned area discrimination using MODIS/ASTER (MASTER) airborne simulator data*. Remote Sensing of Environment, 115, 2702-2709.

Remote Sensing of Environment 115 (2011) 2702–2709

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Evaluating spectral indices for burned area discrimination using MODIS/ASTER (MASTER) airborne simulator data

S. Veraverbeke [a,*], S. Harris [a,b], S. Hook [a]

Remote Sens. **2011**, *3*, 2403-2419; doi:10.3390/rs3112403

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Article

Evaluating Spectral Indices for Assessing Fire Severity in Chaparral Ecosystems (Southern California) Using MODIS/ASTER (MASTER) Airborne Simulator Data

Sarah Harris [1,2], Sander Veraverbeke [2,*] and Simon Hook [2]

Remote Sensing of Environment xxx (2012) xxx–xxx

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An alternative spectral index for rapid fire severity assessments

S. Veraverbeke*, S. Hook, G. Hulley

What's next?

Landsat archive for SoCal 1985-2011

Analyzing spatio-temporal patterns of burned area, fire severity and carbon emissions

Analyzing the significance of Santa events versus 'regular' fires