SAFARI 2000 Pre- and Post-fire Reflectance near Kaoma, Zambia, Dry Season 2000

Abstract

The main goal of this study was to analyze the possibility of estimating combustion completeness based on fire-induced spectral reflectance changes of surface features by the development of relationships between combustion completeness and pre-fire to post-fire spectral reflectance changes, in the green, red, and near-infrared spectral domains (equivalent to Landsat ETM+ channels 2, 3, and 4). Experimental burns were carried out in the Western Province of Zambia, during the SAFARI 2000 Third Intensive Field Campaign in August and September of 2000.

Several measurements of leaf reflectance and transmittance were performed using an External Integrating Sphere connected to a FieldSpec UV/VNIR Spectroradiometer. In addition, reflectances and transmittances of both upper and lower leaf faces were measured for three tree species: *Julbernardia globiflora*, *Isoberlinia angolensis*, and *Brachystegia spiciformis*. Measurements of the *Brachystegia* were collected from green and senesced leaves.

Fieldspec radiometer measurements were performed in specific vegetation formations such as *dambos* (hydromorphic grasslands) and *miombo* woodlands. Some measurements were collected in transects while others were collected using a sampling frame in a grid shape with 16 plots. Pre- and post-fire biomass measurements were made along with many of the spectral measurements.

Background Information

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Project: SAFARI 2000

Data Set Title: SAFARI 2000 Pre- and Post-fire Reflectance near Kaoma, Zambia, Dry Season 2000

Site: near Kaoma, Zambia
Westernmost Longitude: 24.80 E
Easternmost Longitude: 24.80 E
Northernmost Latitude: 14.79 S
Southernmost Latitude: 14.79 S

Data Set Citation:

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Data File Information

There are three sets of measurements in this data set: reflectance measurements from the FieldSpec Radiometer; reflectance and transmittance measurements from the Integrating Sphere; and calculations that integrate biomass data with spectral data. The data files from each instrument are listed in the table below:

Data Files

Instrument	Features	Data Files	Dates
FieldSpec Radiometer	Signatures	spectral_signatures	August 25
	Transects	trans_burned_dambo_spectra	Aug 25, 28, 30 Sept 1, 4
		trans_woodland_spectra	September 4
	Pre- and Post-Fire	pre-fire_dambo_spectra	August 25
		post-fire_dambo_spectra	August 28
		pre-fire_woodland_spectra	August 29, 30
		post-fire_woodland_spectra	September 1
Integrating Sphere	Miombo Woodland Species	Brachystegia_sphere	August 23
		Julbernardia_sphere	
		Isoberlina_sphere	
Comparisons of	Pre- and Post-	ETM_Biomass_CC	August 24

Biomass, Spectra, and Combustion Completeness	Fire Dambo		(pre-fire) and August 25 (post -fire)

FieldSpec files

The columns in the FieldSpec radiometer files are identified in the table below for each file. The wavelength units are in microns; all other columns are reported in fractional reflectance (multiply by 100 to get percent).

Spectral Signatures					
Wavelength	Charcoal	Dry Grass	Soil		
Woodland Transect					
Wavelength	Dry Grass	Recently burned miombo	Old burned miombo	Unburned miombo	
Burned Dambo Transect					
Wavelength	tr_day25/08	tr_day28/08	tr_day30/08	tr_day1/09	tr_day4/09
Pre-fire Dambo					
Wavelength	plot1	plot2	plot3	.....	plot16
Post-fire Dambo					
Wavelength	plot1	plot2	plot3	.....	plot16
Pre-fire Woodland					
Wavelength	plot1	plot2	plot3	.....	plot16
Post-fire Woodland					
Wavelength	plot1	plot2	plot3	.....	plot16

Integrating Sphere Files

The first column in each file is wavelength, in nanometers, and the rest of the columns are either percent reflectance or transmittance. Below is a key to some of the abbreviations used in the column names to describe what was measured:

R Reflectance

T Transmittance
b Leaf lower surface
a Leaf upper surface
1-5 Repetitions

ETM+ Band Estimation, Biomass, and Combustion Completeness

The file "**etm_biomass_cc.csv**" contains the columns described in the table below.

Column	Description	Units
Quadrant	quadrant identifier	num.
Pre-fire reflectance band 2	Pre-fire reflectance measurement in ETM+ channel 2 wavelengths	%
Post-fire reflectance band 2	Post-fire reflectance measurement in ETM+ channel 2 wavelengths	%
Spectral difference band 2	Pre- to post-fire spectral difference in ETM+ channel 2 wavelengths	%
Pre-fire reflectance band 3	Pre-fire reflectance measurement in ETM+ channel 3 wavelengths	%
Post-fire reflectance band 3	Post-fire reflectance measurement in ETM+ channel 3 wavelengths	%
Spectral difference band 3	Pre- to post-fire spectral difference in ETM+ channel 3 wavelengths	%
Pre-fire band channel 4	Pre-fire reflectance measurement in ETM+ channel 4 wavelengths	%
Post-fire reflectance band 4	Post-fire reflectance measurement in ETM+ channel 4 wavelengths	%
Spectral difference band 4	Pre- to post-fire spectral difference in ETM+ channel 4 wavelengths	%
Pre-fire biomass weight	biomass before fire	g
Post-fire biomass weight	biomass post fire	g
Combustion completeness	Combustion completeness	%

Study Area

Field work was conducted near Kaoma (elevation 1200 m), in the Western Province of Zambia. The study area is located in the wetter Zambezian miombo woodland (White, 1983), characterized by having rainfall higher than 1000 mm per year, but less when occurring on Kalahari sand, which is the case in the Kaoma area. The woody vegetation here is dominated by species in the subfamily Caesalpinioideae (family Fabaceae), particularly in the genera *Brachystegia*, *Julbernardia*, and *Isoberlinia*. Miombo woodlands cover approximately 2.7 million km^2 in Africa, in regions with mean annual rainfall between about 700 mm and 1400 mm (Frost 1996). Interspersed within the woodlands are broad, hydromorphic grasslands, called *dambos,* which can cover up to 40% of the landscape in some areas (Desanker et al,. 1997). Dambos are distinctive features of the miombo region, which occupy seasonally-waterlogged, shallow valley depressions (Campbell et al*.,* 1996). The dominant grass of dambos in the study area is *Loudetia simplex* (Nees) C.E. Hubb. Mean annual rainfall in Kaoma District is 917 mm, most of which falls during the wet season, between late November to April. Mean daily temperature in July, during the middle of the dry season, varies between 17.5 and 20.0º C (Hoffa et al*.,* 1999).

Burnt and unburnt areas at the Namalazi dambo, showing dry grass in the background and charcoal and bare soil in the foreground.

In the close-up image above you can see an intact patch of dry grass among the burned grasses.

Measurements were performed both in dambo and woodland sites, only in the grass layer dominated by *Loudetia simplex.* In the woodland site, spectral measurements are a mixture of the spectral signals of grass, leaf and twig litter, and soil. In the dambo site, measurements are a mixture of the grass and soil spectral signals. Site and fire information is provided below, along with the instruments used for the measurements in this data set.

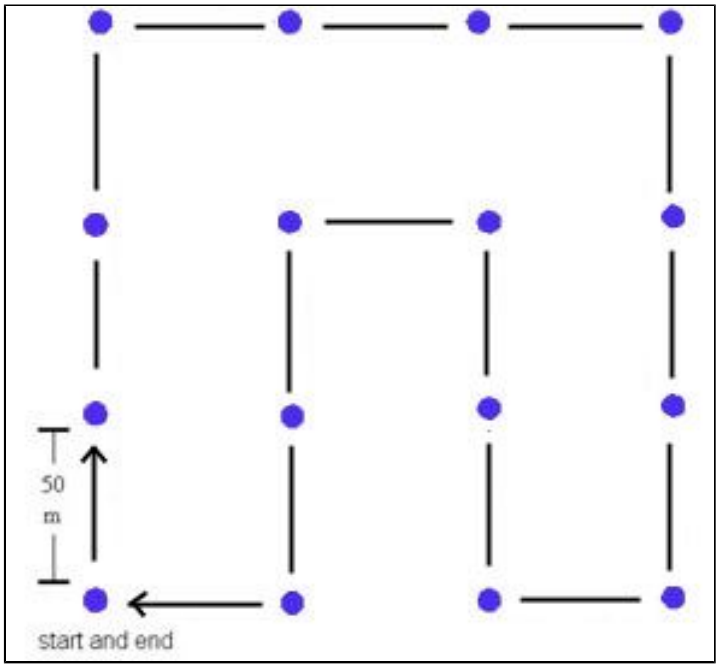
Site	Latitude	Longitude	Date of Prescribed Fire	Size of Fire
Namalazi Dambo	14.81° S	24.51° E	August 25, 2000	125 ha
Namalazi Woodland	14.82° S	24.48° E	September 1, 2000	95 ha

Instrument	Manufacturer
External Integrating Sphere 1800-12S	LI-COR, Inc., Nebraska, USA
FieldSpec UV/VNIR Spectroradiometer	Analytical Spectral Devices, Inc., Colorado, USA

Spectral Reflectance Measurements

Three types of spectral measurements were made: (1) pre- and post-fire spectral measurements in dambo and woodland sites; (2) transects within a burned dambo and woodland site; and (3) pure spectral measurements of soil, vegetation, and charcoal.

Pre- and post-fire spectral measurements were performed in 150 by150 m plots. The sampling frame is a grid of intersecting lines placed 50 m apart, oriented in a North-South direction, yielding 16 measurement points, or quadrats. Spectral reflectance of the 16 quadrats were measured prior to the fire and immediately after the fire, using a FieldSpec VNIR spectroradiometer, over the range 400 nm to 900 nm, with a 1.4 nm sampling interval. At the beginning of each set of measurements, the reflectance of a white Spectralon reference plate was measured in order to convert the measured radiance into reflectance factor values.

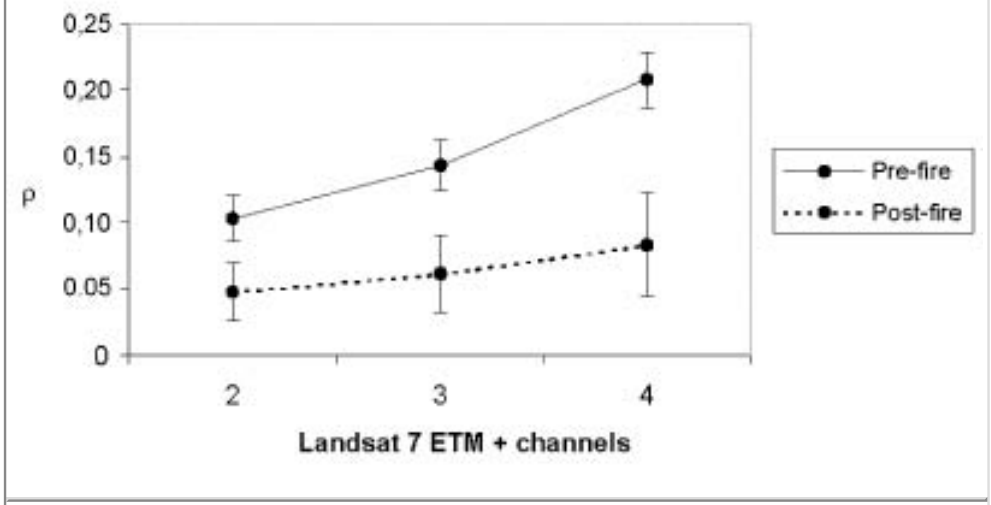


Transects in the dambo and woodland sites were approximately 70 m long. Spectral measurement were taken every two steps (the sampling size 43). The burnt area transect in the dambo site were taken over several days to monitor the vegetation recovery after fire. Pre- and post-fire spectral measurements in the dambo sampling plots were collected on the 24th and 25th of August 2000,

respectively. Spectral change measurements in the woodland were made on the 30th of August 2000 (pre-fire) and the 1st of September 2000 (post-fire). Transects in the woodland sites were all from the 4th of September, with unknown burning dates for the recently burned miombo and old burned miombo reflectance columns.

ETM+ Band Estimation, Biomass, and Combustion Completeness

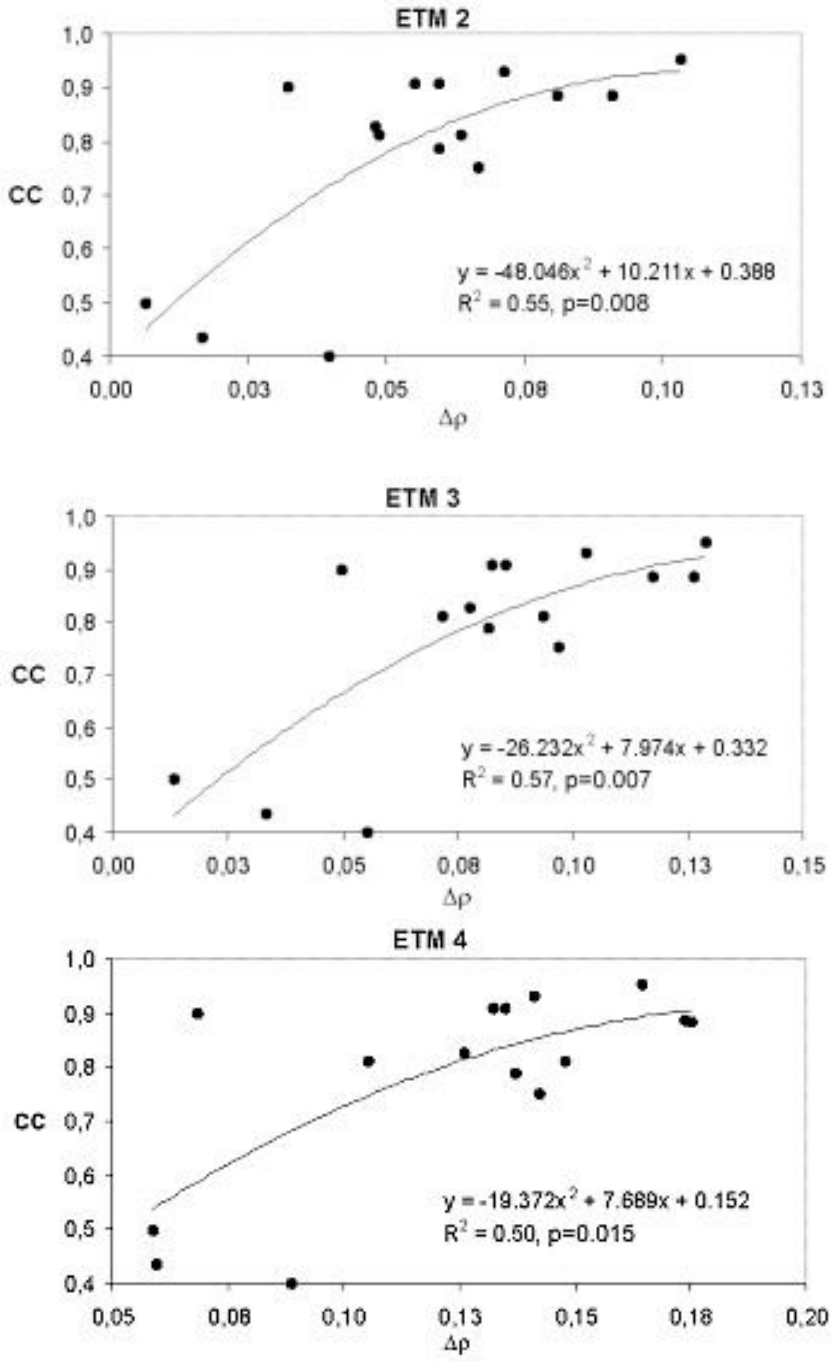
The pre- and post-fire reflectance measurements were converted into band equivalent reflectance using the spectral response functions of Landsat 7 ETM+ channels 2, 3, and 4, to obtain mean reflectance factor values over the spectral range of each channel.



Mean ±1 standard deviation pre-fire and post-fire spectral reflectance signatures for the 15 plots of the Namalazi dambo burn. The X axis represents the three simulated bands equivalent to Landsat 7 ETM+ bands 2, 3 and 4.

The pre-fire vs. post-fire reflectance factor differences were used in a regression analysis to estimate combustion completeness (CC). Combustion completeness was calculated as the ratio of the pre-fire and post-fire biomass differences and the pre-fire biomass. The non-linear relationships of the difference between pre-fire and post-fire reflectance in the spectral domain of the ETM+ sensor band 2 (green), band 3 (red), and band 4 (near-IR) channels and CC are shown below for the Namalazi dambo burn. A problem with the spectroradiometer invalidated the post-fire reflectance measurement at one of the quadrats,

reducing the sample size to 15 observations.



Fitted non-linear regressions between pre- and post-fire spectral reflectance differences in the spectral domain of the ETM+ green (ETM2), red (ETM3), and NIR (ETM4) bands, and combustion completeness for the 15 clipped plots from the Namalazi dambo burn.

Prior to the date of burning we clipped the grass in each quadrat, put it into a

bag and weighed it. The sampling procedures used before burning were repeated after the fire. Post-fire fuel sampling was performed on 16 quadrats adjacent to those measured prior to the fire. The only significant difference was that charcoal and ash present in the quadrats were collected with a portable vacuum cleaner.

Leaf Level Measurements

Leaves were collected from the three dominant Miombo species in the region. These leaves were put into the integrating sphere to perform the spectral measurements. There are three files of leaf level measurements made of the Miombo woodland species *Brachystegia spiciformis*, *Isoberlinia angolensis*, *and Julbernardia globiflora*.

Spectral measurements at the leaf level were made using portable instruments (spectroradiometer + integrating sphere). Representative leaves were collected from the dominant miombo species and placed in an integrating sphere for measurement of their spectral signatures. All measurements were made in the town of Kaoma, shortly after collection of the samples in the field. *Brachystegia spiciformis* is the dominant tree species near Kaoma, and was selected for a study of the detectability of understory burns. The dry *Brachystegia* leaves were not oven-dried; they were dry (senesced) in the field.

NOTE: Data for this study were collected under research project POCTI/CTA/33582/99 (Reduction of uncertainties in estimates of atmospheric emissions from fires in southern Africa), Foundation for Science and Technology, Ministry for Science and Higher Education, Portugal.

Additional Sources of Information

Related Data Sets

Biomass measurements were made along with many of the spectral measurements reported here. For additional information on the biomass data, see Pereira et al. (2003).

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