DISCRIMINATION AND BIOPHYSICAL CHARACTERIZATION OF CERRADO PHYSIOGNOMIES WITH EO-1 HYPERSPECTRAL HYPERION

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Abstract. The Brazilian savanna, locally known as "cerrado", is the most intensely stressed biome with both natural- and human-induced pressures. In this study, we aimed to improve discrimination and characterization of the Brazilian cerrado physiognomies using hyperspectral Hyperion imagery, the first space-borne imaging spectrometer onboard the NASA's Earth Observing-1 (EO-1) platform. A Hyperion image was acquired over the Brasilia National Park (BNP) on July 20, 2001. Various optical measures which took a full advantage of hyperspectral remote sensing were employed and applied to the atmospherically-corrected Hyperion data. These included the 1st-order derivative-based green vegetation index (1st-DGVI), ligno-cellulose absorption index, spectral albedo, and shortwave-infrared (SWIR) spectral unmixing. All these optical measures were correlated well with field-estimates of landscape component cover fractions. Especially, the SWIR spectral unmixing results simultaneously biophysically-characterized and discriminated the cerrado physiognomies. These preliminary analyses showed a great potential of hyperspectral remote sensing in characterizing/discriminating the land covers in the Brazilian cerrado.

Keywords: hyperspectral remote sensing, cerrado, land cover characterization, land cover discrimination, EO-1, Hyperion.

1. Introduction

The savanna, typically found in the sub-tropics and seasonal tropics, are the dominant vegetation biome type in the southern hemisphere, covering approximately 45 % of the South America. In Brazil, the savanna, locally known as "cerrado", is the most intensely stressed biome with natural environmental pressures (e.g., the strong seasonality in weather, extreme soil nutrient impoverishment, and widespread fire occurrences) and rapid/aggressive land conversions (Skole et al., 1994; Ratter et al., 1997). Better characterization and discrimination of cerrado physiognomies are needed in order to improve understanding of cerrado dynamics and its impact on carbon storage, nutrient dynamics, and the prospect for sustainable land use in the Brazilian cerrado biome.

In this study, we aimed to improve discrimination of the Brazilian cerrado physiognomies through biophysical characterization with hyperspectral remote sensing. We used Hyperion, the first satellite-based hyperspectral imager, onboard the Earth Observing-1 (EO-1) platform.

2. Materials and Methods

Our study sites were located in the Brasilia National Park (BNP) in the northern Federal District, Brazil (S 15^o 40', W 48^o 02'). This preserved area contains several of the major "core" cerrado vegetation associations (physiognomies), including cerrado grassland (camp limpo), shrub cerrado (campo sujo), wooded cerrado (cerrado ralo), cerrado woodland (cerrado tipico), and gallery forest (mata de galeria) in the order of increasing arboreous cover (Ribeiro and Walter, 1998).

The first four major cerrado physiognomies described above were structurally characterized using ground transect surveys. At each site (physiognomy), landscape were vertically stratified into an arboreous (shrubs/trees) overstory layer and herbaceous understory layer dominated by grasses, in addition to a background soil/litter layer. Component cover fractions of each layer were then measured using a pin-point technique along a randomly-chosen 100 m transect. The landscape components considered in the measurements were: photosynthetic vegetation (PV), woody materials, and crown covers for the overstory, PV and standing litter for the understory, and soil and surface litter for the background surface layer.

Hyperspectral Hyperion data were acquired over the field sites on July 20, 2001 during the field measurement campaign. Hyperion collected full range spectral data (400-2400 nm) in 10 nm intervals (full-width at half maximum = 10nm) at a 30 m ground spatial resolution. The data were preprocessed and radiometrically-calibrated into a Level 1A product at the TRW Hyperion data processing facility. The data were further processed to correct for several known artifacts in the Level 1A products and then converted to ground reflectances using a MODTRAN4-based atmospheric radiative transfer code (ACORN4, `http://www.aigllc.com/acorn/intro.asp`). The atmospherically-corrected Hyperion data were compared to airborne spectrometer (Analytical Spectral Devices, Inc., Boulder, CO, USA) data collected at a large dry pasture field in the north of BNP near the Hyperion overpass time, but on the next day. An aircraft was flown "below the atmosphere" at 150 m AGL. The airborne data were calibrated to ground reflectances by taking a ratio to the readings made over a calibrated Spectralon white reference panel before and after the flight. The Hyperion and airborne spectrometer data were statistically similar, indicating good accounting of atmospheric constituents in the Hyperion correction.

Pixels over the field sites were extracted from the atmospherically-corrected Hyperion image. GPS coordinates of the sites and low-altitude aerial photos were used to locate the sites in the image. In addition, another set of pixels were extracted over gallery forest, cultivated pasture, and lake water (Santa Maria Lake at the center of BNP) for comparisons.

3. Results

Field Measurements. Measured landscape component cover fractions of the four cerrado physiognomies as well as the field site locations are summarized in Table 1. The herbaceous layers were dominated by senescent tissues, while the shrub/tree layer were still green at the time of this field campaign. As used for the basis on many cerrado classification schemes (e.g., Ribeiro and Walter, 1998), the crown cover fractions increased from the cerrado grassland to cerrado woodland sites with a discrete increase between the shrub cerrado and wooded cerrado sites. There was a general increase (decrease) in the PV (NPV) cover fractions with an increase in the crown covers, except for the wooded cerrado site. Two of the four sites, the wooded cerrado and shrub cerrado sites, were dominated by the species that grow quickly after burnings and that remained green, which resulted in a larger green cover in the wooded cerrado site than the cerrado woodland site. Nearly no soils were exposed at any of the sites.

Table 1. Landscape Component Cover Fractions of the Cerrado Physiognomies Measured in the Field Sites

Site Name (Physiognomy)	Site Location (Lat./Lon.)	Crown (%)	Green (PV) (%)	NPV (%)	Soil (%)
Cerrado Grassland	N15°39'55"/ W48°01'52"	1	18	82	< 1
Shrub Cerrado	N15°35'20"/ W48°00'25"	3	23	76	< 1
Wooded Cerrado	N15°36'26"/ W48°01'47"	10	34	63	3
Cerrado Woodland	N15°43'58"/ W48°00'11"	13	30	69	< 1

Hyperion Reflectance Data. The Hyperion hyperspectral signatures clearly depicted the differences between pasture, gallery forest, and the other four cerrado physiognomies (Figure 1). Spectral signatures in the visible and near-infrared (NIR) regions for the cerrado physiognomies showed small differences, but with the red-NIR reflectance contrast corresponding well with green cover fractions (Figure 1, Table 1). The reflectance values at the shortwave-infrared (SWIR) region (1400 – 2500 nm) and the ligno-cellulose absorptions

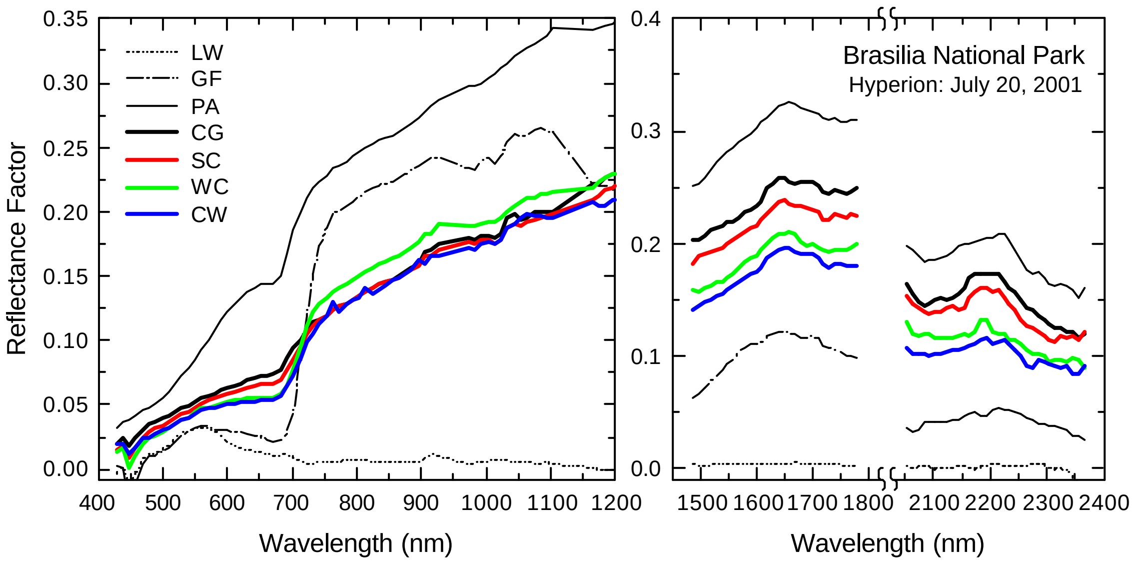

Figure 1. Mean Hyperion reflectance spectra for the four cerrado physiognomies of cerrado grassland (CG), shrub cerrado (SC), wooded cerrado (WC), and cerrado woodland (CW). Mean Hyperion spectra for lake water (LW), gallery forest (GF), and cultivated pasture field (PA) were also plotted for comparisons.

at 2090 nm and around 2280 nm wavelengths showed larger differences among the cerrado physiognomies (Figure 1). The cerrado physiognomies with less crown cover (and, thus, more NPV cover) showed higher SWIR reflectances and deeper ligno-cellulouse absorpotions (Table 1).

Correlative Analysis with Biophysical Data. In order to more quantitatively analyze these spectral signatures, we focused on two spectral regions that corresponded well to relative differences in physiognomies, namely, (1) the red-NIR transitional region (650-800 nm) and (2) the SWIR2 spectral region (2000-2400 nm), and performed a correlative comparison with cover

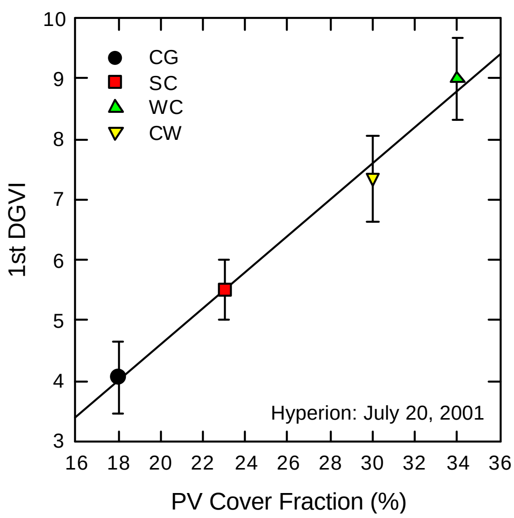

Figure 2. First-DGVI plotted against field estimates of PV cover fractions for cerrado physiognomies.

fractions. We employed various optical measures to take the full advantages of hyperspectral remote sensing, including the 1st-order derivative-based green vegetation index derived from local baseline (1st-DGVI) (Elvidge and Chen, 1995), SWIR2 spectral albedo (an integral of reflectances from 2100-2350 nm), ligno-cellulose absroption index (Elvidge, 1988), and 3-endmembers SWIR spectral unmixing (Asner and Lobell, 2000). Details of these methods were provided in the corresponding references.

In Figure 2, the 1st-DGVI values were plotted against the green cover fractions. The 1st-DGVI and green (PV) cover fractions correlated very well.

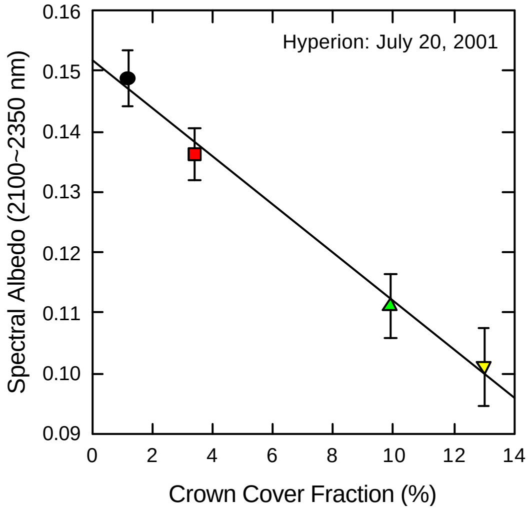

Figure 3. SWIR spectral albedo plotted against field estimates of crown cover fractions.

Similarly, the spectral albedo of the SWIR region (2100-2350 nm) and ligno-cellulose absorption indices for 2090 and 2280 nm were correlated very well with the crown and NPV cover fractions, respectively (Figures 3, 4). The ligno-cellulose absorption indices, however, had large standard deviations (Figure 4) due most likely to the low signal-to-noise ratios of the Hyperion sensor in this wavelength region (< 30:1).

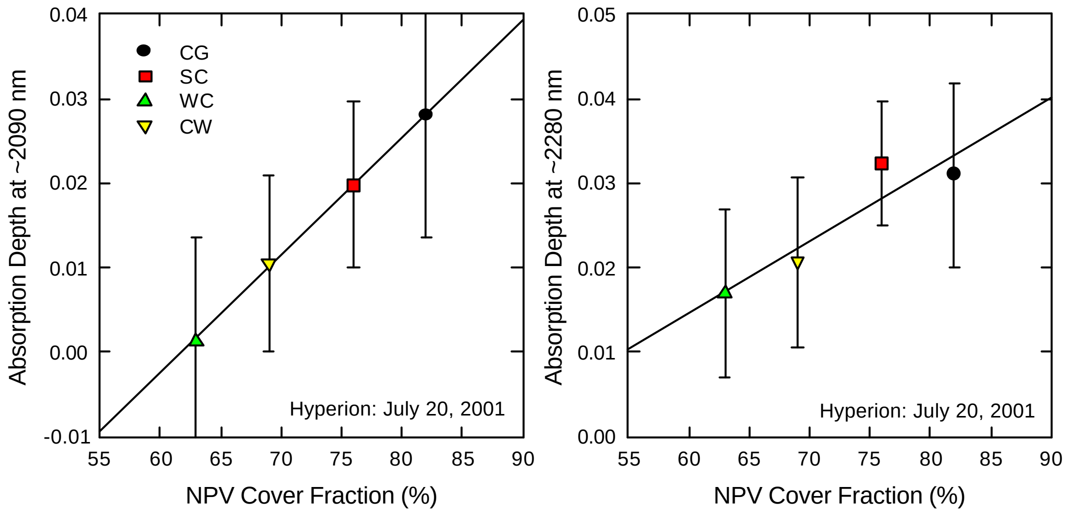

Figure 4. Ligno-cellulose absorption depths plotted against field estimates of NPV cover fractions.

Finally, the SWIR unmixing results from the Hyperion image were compared to an existing vegetation map for BNP (Macedo,1992). The regional fractional estimates were consistent with the vegetation map (Figure 5). Largest values of green vegetation fractions corresponded well to the occurrences of gallery forest along stream lines. Similarly, relatively large values of green vegetation fractions corresponded spatially well with wooded cerrado and cerrado woodland, while cerrado grassland and shrub cerrado areas were consistent with large NPV fractions.

4. Conclusions and Discussions

In this study, we evaluated the utility of hyperspectral remote sensing in biophysical characterization and discrimination of cerrado physiognomies by taking an advantage of a newly available satellite-based imaging spectrometer, EO-1 Hyperion. The atmospherically-corrected hyperspectral reflectance of Hyperion clearly depicted such diagnostic absorption features of vegetation as the red edge, red-NIR transition, and ligno-cellulose absorptions. Likewise, these spectral features were found to be corresponding well with biophysical characteristics (i.e., landscape component cover fractions) of cerrado physiognomies. As the cerrado physiognomic classes are based on differences in the proportion of a grass understory and tree/shrub overstory layer, the cover component fractional estimates of green vegetation, NPV, and soil with the SWIR spectral unmixing resulted in not only biophysically characterizing, but also discriminating cerrado physiognomies. These preliminary analyses showed a great potential of hyperspectral remote sensing in biophysical characterization as well as discrimination of the land covers in the Brazilian cerrado.

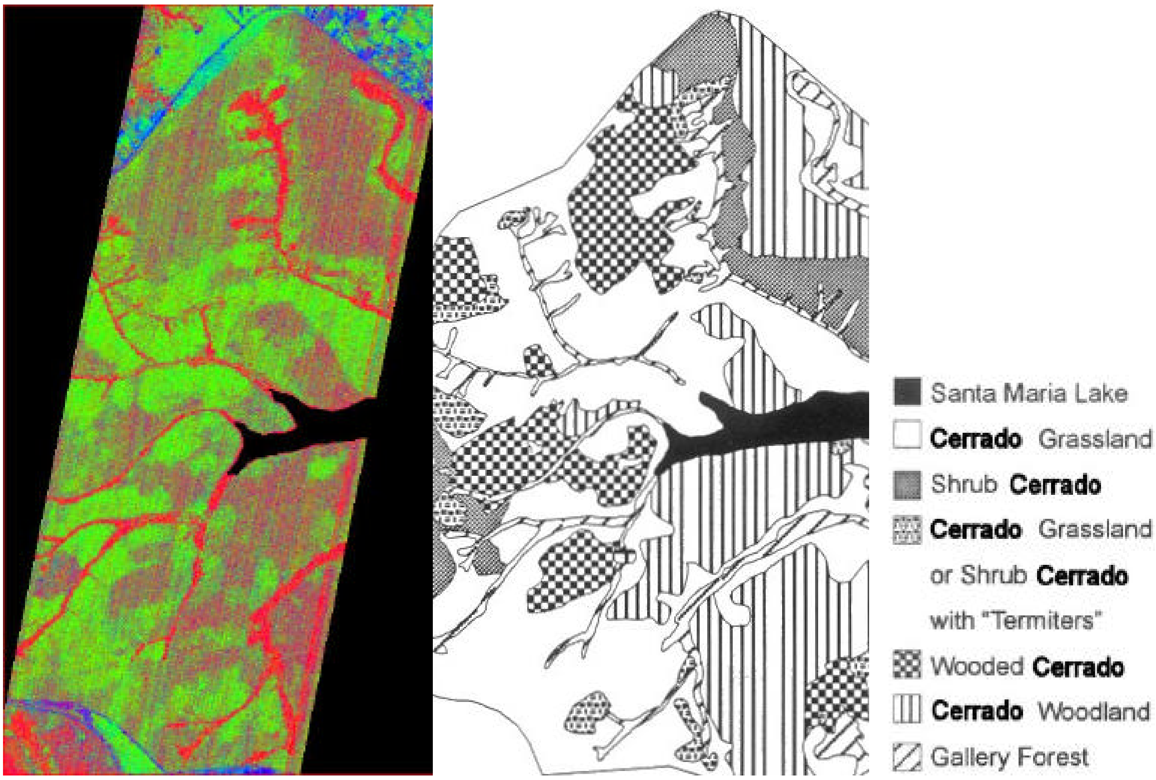

Figure 5. Color composite of green vegetation (red), total litter (green), and bare soil (blue) fractions in comparison to a vegetation map adapted from Macedo (1992) for the Brasilia National Park.

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