LEAF SPECTRAL BEHAVIOR AND CHLOROPHYLL CONTENT OF *MIMOSA HOSTILIS* CANOPY IN A SEMIARID ENVIRONMENT

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Abstract

Insurance and efficiency to monitoring and the use of interacting methods for an accurate diagnosis of the vegetation, mainly those from tropical regions, are essentials to contribute to future development management actions. Remote sensing, biological traits associating structural and biochemical data will permit evaluate the behavioral picture of a dominant specie in vegetation that cover great areas. This study aimed to identify the leaf spectral signature features and structural traits related to dominant specie and photosynthesis implications, relating it with environmental stress consequences and discussing critically monitoring using remote sensing methods. Multispectral analysis and hyperspectral spectroradiometer “FieldSpec Handheld” by Analytical Spectral Devices (ASD) from georeferenced points were made. Perceptible differences were detected for mean values of chlorophyll *a* and *b* from field data. The use of Hyperion hyperspectral image showed potential to infer the condition of vegetation regeneration analyzed and different intensities of chlorophyll.

Keywords: Hyperspectral, vegetation stress, pigments, remote sensing method.

Introduction

Remote sensing data is widely used for canopy monitoring in different vegetation types. Though it is possible to analyze biochemical characterization of plants in different wavelengths of the electromagnetic spectrum, apparently few is known about spectral traits and chlorophyll content into leaves in tropical plants. It can be also used to modeling and to simulate biological and physical processes.

The chlorophyll quantification, mainly those related to the vegetation with few species dominant assumes greater relevance when the intention is to evaluate its biological condition. Different crop species were evaluated through chlorophyll quantification and hyperspectral indices of the canopy, in an area with different sizes (Ferri, Formaggio & Schiavinato, 2004; Jarocinska & Zagajewski, 2009).

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The literature shows different approaches to quantify the chlorophyll and hyperspectral indices of vegetation to inform, to estimate and to produce models that can inform about the health of plants photosynthetic performance (Haboudane et al., 2004; Ferri, Formaggio & Schiavinato, 2004; Malenovský et al., 2006; Wu et al., 2008).

The leaf or canopy photosynthetic activity in a crop or forest can inform about the capacity of biomass production as a consequence of photoassimilate quantity. Its use is extensively applied to estimate the efficiency of some crops through remote sensing revealing distinctive reflectance properties (Wamunyima, 2005).

The use of bands for mathematical modeling generates useful vegetation indices (Jensen, 1993). Hyperspectral information is suitable to biological and biophysical variables (Jarocinska & Zagajewski, 2009).

This paper aims to identify the spectral signature and to relate it with leaf surface features and its implications to the adaptations to environmental stress of the dominant specie *Mimosa hostilis* (Mart.) Benth., vulgarly known as “jurema preta” in the Semiarid Region of Northeastern Brazil. This paper discusses aspects of optical traits of the leaf surface that are critical to the development of detailed and accurate monitoring systems. Also, it discusses remote sensing applications associated with fundamental plant mechanisms, mainly those related to the photosynthesis.

2. Material and Methods

2.1 Study Area

All data were collected in 15th November 2010, at the site São José do Sabugi-Paraíba-Semiarid Experimental Field (Figure 1), described at Galvêncio et al. (2010).

Figure 1. Map of the study area highlighting the studied area.

2.2 Multispectral data

Basin for the multispectral analysis was a subset of Landsat 5 satellite image of January 13nd, 2009, the satellite was launched in 1970 and is still collecting reflectance data 180km above ground. The spatial resolution of 30m in 1, 2, 3, 4, 5 and 7 bands and 120m in thermal band. Landsat 5 collects multispectral data in seven spectral bands. Table 1 shows the band numbers and width of the satellite.

Table 1. Multispectral band information of Landsat. Font: www.engesat.com.br.

Band number	Band width (nm)	Color
1	450-520	Blue
2	520-600	Green
3	630-690	Red
4	760-900	Near infrared
5	1550-1750	Medium infrared
7	2080-2350	Distant infrared

2.3 Hyperspectral data

The hyperspectral spectroradiometer “FieldSpec Handheld” by Analytical Spectral Devices (ASD) was used to collect field data of an artificial inoculation trial. This very high spectral resolution device was applied to evaluate biotic and abiotic growth-anomalies of sugar beets in dependence of their spectral reflectance. The used ASD handheld spectroradiometer collects spectral data in a wavelength range of 325nm to 1075nm with an interval of 1.6nm. This results numerous individual bands which represent a nearly contentious reflectance curve. The viewing

angle of the FieldSpec is 25 degrees. Additionally, a low cost GPS solution coupled to a CE computer was used to locate the sampling spots (Laudien et al., 2004).

A white reference plate under the sheet was used to simulate the effect of background.

2.4 GPS data

GPS-data was collected at selected fields in all points of the study area to validate the multi and hyperspectral analysis results.

Multispectral or hyperspectral vegetation indices can be calculated by using the red and near-infrared portions of the spectra as well (Laudien et al., 2004). The index values are significantly correlated to the vitality of the detected plant. In this study, the hyperspectral vegetation index (HVI), following Gitelson et al. (1996), was modified according to Laudien et al. (2004) (see Equation 1-3). Equation 2 presents the one modified spectral vegetation indices (VI). The spatial analysis, both calculation and classification, were accomplished by using the GIS software Erdas ImageTM 9.3 by Leica Geosystems[®] and ArcGISTM 9.3 by ESRI[®].

$$HVI_{Gitelson\ et\ al} = \frac{R750}{R700} (1)$$

Where, R750 = reflectance at 750nm (%) and R700 = reflectance at 700nm (%)

$$VI_{Landsat\ 5} = \frac{RB4}{RB3} (2)$$

Where, RB4 = reflectance of the band 4 and RB3 = reflectance of the band 3.

$$VI_{Hyperion} = \frac{RB40}{RB35}$$

Where, RB40 = reflectance at 752.43nm and RB35 = reflectance at 701.55nm.

In the last step, the results of the VI calculations were classified into nine vitality classes by using the “Quantile Classification Method” of ArcGIS™ Spatial Analyst. To validate and compare the two classified outputs, the GPS polygons of the campaign were to the ArcGIS™ 9.3 project as an overlay layer, proposed by Laudien et al. (2004).

Aiming to relate hyperspectral spectroradiometer features with internal structure of the leaves of *M. hostilis* we measured the traits: thickness of upper and lower cuticle and epidermal layers, mesophyll, palisade and spongy parenchyma, intercellular air spaces, vascular tissues and substomatal chamber to evaluate the internal backscattering

of light inside the leaf. These measures will permit discuss the degree participation of each one with the reflectance and transmittance processes.

3. Results and Discussion

3.1 Spectral response of the FieldSpec handheld

The Figure 2 shows the medium spectral behavior in the visible of *M. hostilis* Benth. to the point from the coordinates $x=738057$ and $y=9245952$ meters. Note that the spectral reflectance in the green band was approximately 27% and in the red band around 20%. The HVI average was 2.002. At this point, the average value for chlorophyll *a* was 21.7, and to *b* was 3.5, on January 23, 2010.

Figure 2. Spectral response of *Mimosa hostilis* measured with FieldSpec in laboratory conditions. (January 23, 2010).

3.2 Spectral response of the Landsat TM 5

The Figure 3 shows the spectral behavior of *M. hostilis* in a semiarid region of Northeast

Brazil using the satellite Landsat5. In general, the different samples showed a similar pattern of spectral behavior. However, there are

perceptible differences for the intensities from reflected energy. The red line coincides with the green line; it showed the same behavior in all spectral bands of the electromagnetic spectrum. Photographs 1 and 2 of the landscape correspond to the points 1 and 2, for red and green lines in the Figure 3. The point 3 corresponds to the black line, which exhibited different intensities of energy reflected from other points in the visible region, and it was approached the energy reflected from the points 1 and 2 to the near infrared and middle regions. It is possible note in the point 3, a lower intensity of reflected energy in the visible when compared to the points 1, 2 and 5. The point 4 showed lower intensities of reflected energy. Photographs 4, 5 and 6 show the landscape related to the points 3, 4 and 5, corresponding to the lines black, yellow and purple, respectively. The points 1, 2 and 3 showed similar features relating to cell structural traits in individuals from different species that have similar development stadium. These points correspond to the vegetation regeneration, indicating that the analysis allows us to infer the condition of vegetation regeneration analyzed and different intensities of chlorophyll due to higher density of green coverage in the point 3.

Through field sampling was possible verify differences in mean chlorophyll *a* of 8.3, 5.7 and 18.8 and chlorophyll *b* of 2.2, 3.0 and 4.7 in the points 1, 2 and 3, respectively. Section 4 showed the least amount of reflected

energy (yellow line) and the highest average amounts of chlorophyll *a*. Section 5 showed the highest energy level reflected in all regions of the electromagnetic spectrum. The $VI_{\text{Landsat 5}}$ average was 1.76, with a minimum of 1.38 and a maximum of 2.17. Considering the average value and comparing the value obtained with the FieldSpec, we found that it represents 88% from the value obtained with the spectroradiometer. It means that even with all environmental interference and variations of the characteristics in the sites studied, the values of vegetation indices obtained from satellite images represent very well the actual percentage of vegetation in the area.

3.3 Spectral response using Hyperion

The using of FieldSpec under field conditions associated with chlorophyll content data of *M. hostilis* individuals in a semiarid environment in a Hyperion hyperspectral image showed interesting results. It was emphasized when we collected data under different environmental conditions (Figure 4).

The average of VI_{Hyperion} was 1.35, representing 68% from the vegetation index obtained through the FieldSpec and 77% from that obtained with the Landsat TM.

It was noted that, even at low spectral resolution, Landsat provides optimal estimates for the vegetation indices in relation to the *M. hostilis*.

Figure 3. Spectral response of *Mimosa hostilis* using Landsat TM 5. Field points sampled (five) and corresponding line color: 1- Red; 2- Green; 3- Black; 4- Yellow; 5- Purple. (November 15, 2010).

Figure 4. Photographs showing the experimental areas with dominance of *Mimosa hostilis*, and the five points used to collect data using FieldSpec and GPS. (November 15, 2010).

Figure 5. Hyperion hyperspectral image showing visited sites (blue dots).

4. Conclusions

The Landsat contributes to obtain optimal estimations to the vegetation index compared with information from high spectral resolution of the Hyperion and FieldSpec. Field data permitted find differences for mean values of chlorophyll *a* when compared with chlorophyll *b*.

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