RELATIONSHIPS BETWEEN SPECTRAL REFLECTANCE AND PHYTOMASS OF THE GROUND LAYER COMMUNITY OF NEOTROPICAL SAVANNA (CERRADO)

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ABSTRACT

Spectral reflectance measurements of 47 1 m^2 plots of the ground layer of the Savanna of Central Brazil were obtained using a Kimoto PM-12A hand-held spectroradiometer at 13 visible bands and 4 near infrared bands of the electromagnetic spectrum. The aboveground phytomass of each plot was clipped, weighted, oven dried and weighted again. An amount of the fresh phytomass (5-15%) was separated from sample in order to estimate the proportion of the photosynthetically active phytomass. The correlation and regression relationships between the reflectance and phytomass data were examined. The results are: a) fresh and dry total phytomass showed negative correlations for all spectral bands with highest r^2 at λ = 575 nm; b) fresh and dry green phytomass presented negative correlations for all visible bands and positive for near infrared bands; c) fresh phytomass (both, total and green) showed higher r^2 than dry phytomass; and c) the bands that presented best positive and negative correlations with green phytomass were combined to generate vegetation indices. Improved r^2 were achieved, with the best performance obtained by TVI.

1. INTRODUCTION

Quantitative remote sensing of vegetation cover extensively explores the differential behavior of leaf reflectance in the visible (VIS) and in the near infrared (NIR) portions of the spectrum (8). Combinations of reflectance measurements combined into indices are widely used to estimate vegetation cover phytomass commonly named as Vegetation Indices (VI) (17).

Multiple diffuse reflections of sun electromagnetic radiation inside the leaf lead to high reflectance in the near infrared band where the leaf absorbtance is very low. The same mechanism is responsible to the highly efficient VIS radiation retention capacity by the photosynthetic pigments present in leaf tissues(9).

The accumulation of phytomass by a vegetation cover, when followed by increases in the ground Cover Index and in the Leaf

Area Index (LAI), enhances the difference between the behavior of leaf reflectance in those two spectral bands (2). This is true up to a LAI value of ca. 5 where the variations of the reflectance curve with the phytomass increment quickly saturates (3,16).

The wiltting and the changes in leaf orientation caused by water deficit decrease the horizontal component of the LAI of a canopy which result in a reduction of the NIR reflectance of a water stressed vegetation cover (8).

Since water stress directly controls the stomatal behaviour, it is an important constraint to the photosynthetic activity (13). Therefore Vegetation Indices derived from combinations of NIR and VIS reflectances measurements have the potenciality to estimate biological activities directly related to the primary productivity (18).

On this basis, many efforts are being made in order to develop systems to monitor the dynamics of the vegetation cover in regional and continental scale by means of the observation of its photosynthetic activity, estimated through Vegetation Indices (14, 15, 7).

Although the Vegetation Index approach to study vegetation cover is being applied worldwide, its concepts are derived from basic researches carried out in temperate grasslands (10). Basic researches of this nature on tropical ecosystems are scarce specially in South America. A pioneer research was developed in Central Brazil (11) observing the relationships between total phytomass, vegetation water content and spectral reflectance calculated from in situ measurements and from MSS-Landsat data.

Its results encourages the continuation of the research which is the aim of the present one. The objective of this work is to evaluate the relationships between spectral reflectance and vegetation parameters of the ground layer of the Tropical Savanna of Central Brazil in order to subsidize the utilization of remotely sensed radiometric data for Neotropical Savanna monitoring.

2. GENERAL CHARACTERISTICS OF THE "CERRADO"

"Cerrado" is the regional name of the Neotropical Savanna that extends over 180 millions ha in Central Brazil, a region which is characterized by the alternation of well defined wet and dry seasons (5). Depending on the soil type and on the proximity of the water table the physiognomy of the vegetation in this region may vary from a deciduous forest to a herbaceous meadow, but the dominant formation is the Cerrado (12).

The Cerrado normally occurs on oxisols with deep water table, low pH (4.5 - 5.5), low organic matter and nutrient content sometimes followed by high levels of iluminium content (12). The Cerrado is a vegetation formed by the superposition of three synusiaes, i.e.: tree, shrub and ground layer (6).

The tree and the shrub layers, defferenciated only by the height of its individuals, are characteristically formed by sclerophyllous perenial plants with thick bark and irregular branching pattern, which evidences the action of the fire as an important factor in the ecology of this ecosystem (6). The Cerrado can be divided into three physiognomic groups according to the Cover Index of the combination of the tree and the shrub layers: Dense Cerrado (51-70%), Typical Cerrado (21 - 50%) and Sparse Cerrado (1 - 20%) (12).

The ground layer composed of grasses and small shrubs, is present in all of the three physiognomic group without much variation in the biomass (6). Though predominantely perennial, it is looses much of its green biomass during the dry season (6). This behaviour is mostly attributable to the grasses (1) which, unlike the shrubs and trees, are not phreatophytes (6).

The accumulation of dead biomass induces natural fires which stimulates shoot sprouting and flowering of many species (6). In both burnt and unburnt Cerrado the ground layer responds quickly to the precipitation with increment in live biomass (12, 1).

The vegetation covers analised in the present study are mostly examples of Sparse Cerrado and some cases of Typical Cerrado. These were selected in the following locations near Brasília: A test area of the EMBRAPA's Cerrado Research Center, a test area of the Brasilia University and a biological reservation of the Brasilia's Zoobotanical Foundation.

3. MATERIALS AND METHODS

The sample sites were selected with the aid of a digitally processed TM-Landsat data collected in the previous year (9-2-85). TM-5 band was found more suitable for this procedure because of its larger dynamic range in the studied scene when compared with the other bands. A General Electric Image-100 System was utilized for the image digital processing.

Through a Supervised Density Slicing procedure it was observed that the Typical and The Sparse Cerrado Vegetation occupy the medium density levels in the scene histogram. An Equidistibuition Density Slice algorithm was applied to the algorithm in order to discriminate spectral classes within the medium density levels. Four spectral classes were related to the aimed vegetation types. Sample sites were defined in centers of homogeneously classified image fields. Field data collection was realized in May 1986, during the beginning of the dry season.

In each sample site 9 samples 1m x 1m were stabilished by the interceptions of a 50m x 50m grid covering a square of 1 hectare. The exact locations of the $1m^2$ samples were randomly determined by tossing backwardly a tagged stick which pointed the south-eastern corner of a $1m^2$ square.

The $1m^2$ samples were bounded by stakes and string. Reflectance measurements were obtained with a hand-held Kimoto radiometer PM-12A which measures spectral radiance in 10nm bands centered at every 25 nm from 400 nm to 700 nm and at every 100 nm from 750 nm to 1050 nm. A Barium sulfate (BaS) plate was used for the calculation of the reflectance factor. The radiometer was held by a standing observer keeping a 45^{o} viewing angle perpendicularly to the sun azimuth. This illumination-viewing geometry was chosen in order to minimize the variations in the directional reflectance due to the movement of the Sun since measurements were made from 9:00 to 11:30 a.m.. A 10° field of view results in an average $0.25 m^2$ in the ground. Three replicates were obtained within the $1 m^2$ sample proceeded and followed by measurements on the BaS plate with the same illumination viewing geometry.

After the collection of the radiometric data, the above ground phytomass within the $1 m^2$ sample was trimmed at ground level and kept in plastic bags. Detached dead leaves and debris from former fires were discarded.

Fresh Total Phytomass (FTP) was obtained by weighting all the collected material. A sample of 5-10% of this total was randomly drawed for the estimation of the proportion of green phytomass. Fresh weight was obtained before and after these phytomasses were oven dried at $70^{\circ}C$ for 48 hours.

The following vegetation parameters were obtained by this procedure: FTP, Fresh Green Phytomass (FGP), Dry Total Phytomass (DTP), Dry Green Phytomass (DGP), Total Water Content (TWC), Green Phytomass Water Content (GWC) and Proportion of Green Phytomass (PGP), the last one on a dry weight basis.

Statistical analysis of the reflectance and vegetation parameter data were conducted using 47 individual observations made on the $1 m^2$ samples obtained in cloudless sky conditions.

The Simple Linear Correlation Coefficient was obtained for every combination of vegetation parameter and spectral reflectance data.

For vegetation parameters with positive and negative correlation with the spectral reflectance data, vegetation indices were calculated with the data collected in the bands with the best positive and negative correlations.

The following combinations were used for the vegetation indices calculations (A corresponds to the positively correlated reflectance values and B corresponds to the negatively correlated ones):

Band Ratio $R = \frac{A}{B}$

Band Difference $D = A - B$

Normalized Difference $ND = \frac{A - B}{A + B}$

Transformed Normalized Difference $TND = \sqrt{\frac{A - B}{A + B} + 0,5}$

Simple Linear Correlation Coefficients were calculate for all vegetation indices x vegetation parameter combinations.

4. RESULTS AND DISCUSSION

The correlation coefficient (r) obtained from the comparison of the spectral reflectance ($\rho\lambda$) data and the phytomass parameters are graphically displayed in figure 1.

The values for r are all low due to the size of the observation unit which turns the measurements very sensitive to the intrinsic spatial variability of the vegetation structure.

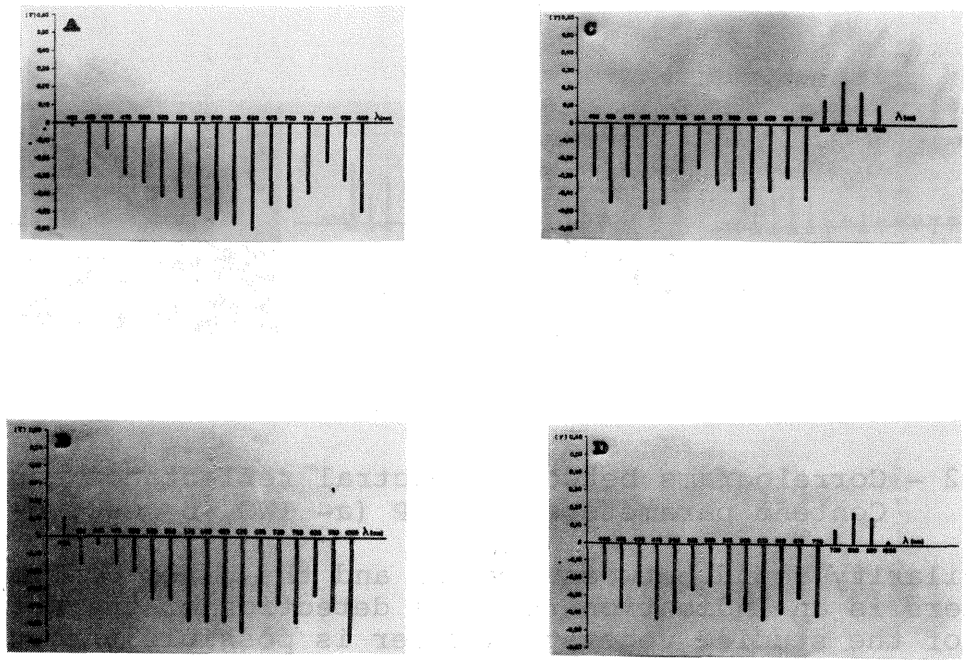

Figure 1 - Correlograms between spectral reflectance and phytomass data (a - FTP; b- DTP; c-FGP; d- DGP)

Total Phytomass both Fresh and Dry are negatively correlated with spectral reflectance in practically all the studied spectral interval (Figure 1 a and b). The behaviour of the relationship is according to the expected in the visible bands but the results found in the near infrared bands indicates that plant parts other than green leaves are decisive in the reflectance characteristic of the vegetation standing crop. Shadows cast by the irregular structure of the studied vegetation and the high reflectance of the oxisols in the near infrared (4) are the reason attributed to this results.

The low values for r obtained for Green Phytomass is also considered to be a consequence of the same interference of standing dead leaves and stems (Figure 1 c and d).

Nevertheless these results presents an expected pattern which supports the application of vegetation indices as an improved estimator of parameters related to the green phytomass.

The general behaviour of the relationships between spectral reflectance and the Water Content parameters and the PGP are very similar, as can be seen in figure 2. They all feature negative correlations in the blue portion of the spectrum, followed by absence of correlation in the rest of the visible spectrum and positive correlations in the near infrared bands.

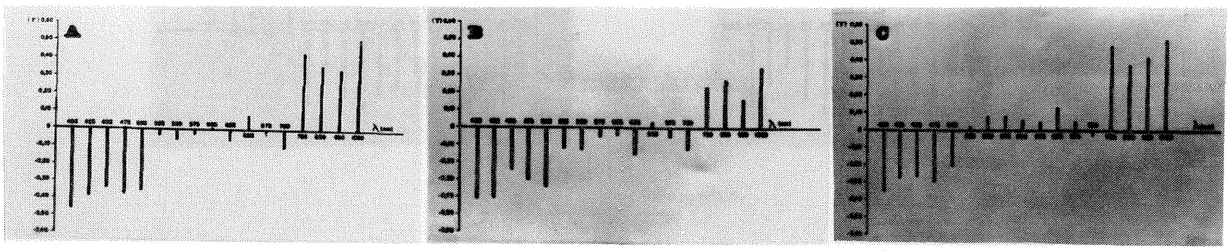

Figure 2 - Correlograms between spectral reflectance and Water Content parameters and PGP (a- TWC, b- GWC, c- PGP).

The similarity found between the PGP and the Water Content parameters is an indication that the detection of the water status of the studied vegetation cover is possible through the observation of PGP. Since this observation is difficulted by increments in the Total Phytomass, the r values for PGB and ρλ are very low in the bands where Total Phytomass is well related to ρλ. The same behaviour is followed by the r values for the Water Content parameters.

The spectral bands selected for the calculation of Vegetation Indices were λ = 850nm and λ = 475nm for the Green Phytomass and λ = 1050nm and λ = 400nm for the Water Content of the correlation analysis between these indices are in table 1.

Except for the TWC little difference can be noted between the results obtained for R, ND and TND, with a slight advantage for the normalized indices. The Vegetation Index developed for TWC presented the best performance although with a r value still not sufficient for a reliable estimation of this parameter by radiometric means.

Fresh Green Phytomass was better indicated in the radiometric measurements than Dry Green Phytomass which is a result of the enhancement of the Water Content of the Green Phytomass in its importance as a component of the Total Phytomass.

V.I. / V.P.	R	D	ND	TND
FGP	0.55	0.31	0.56	0.55
DGP	0.46	0.24	0.48	0.48
TWC	0.49	0.41	0.61	0.59
GWC	0.46	0.32	0.48	0.48

Table 1 - r values between vegetation parameters and vegetation indices from selected bands.

5. CONCLUSIONS

The obtained results do not support the application of combinations of visible and near infrared bands combinations for the total phytomass of the Cerrado ground layer. In the other hand it was found encouraging the possibility to detect its Green Phytomass and Water Content by means of radiometric data combined into Vegetation Indices.

Considered as a consequence of the contribution of the high soil reflectance of oxisols in the red portion of the spectrum (4), it was found that the utilization of spectral radiometric measurements in the red band may not be the best suited for the calculation of the Vegetation Indices. The blue portion of the spectrum presented better relationship with Green Phytomass and Water Content than the red portion.

Normalized Difference presented the best performance as estimator of Green Phytomass and Water Content but generally closely followed by the TND and the R indices.

The results, though restricted to few areas around Brasília, encourage the development of sound radiometric studies of the Cerrado vegetation in order to support the development of suitable indices for the estimation of its ecophysiological conditions and phytomass amount. The greater number of spectral bands that will be utilized in future remote sensing systems such as the MODIS and HIRIS of the EOS reinforces this necessity.

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