TEMPORAL RELATIONSHIP OF NDVI AND SEASONAL VEGETATION IN STRUCTURAL GRADIENT IN PERMANENT PLOTS

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Commission VII, WG VII/3:

KEY WORDS: Remote Sensing, Vegetation, Modeling, Sampling, Ecosystem, IKONOS, Landsat, Temporal

ABSTRACT:

The relationship between remotely sensed data and vegetation has been the object of study for experts in both environmental remote sensing and plant ecology. One difficulty in establishing relationships between remotely sensed reflectance and vegetation is due to seasonal dynamics. The objectives of the study were to derive a model for the relationship between the variation of spectral response of the sensors, climate, and phenology of Cerrado. The site location is the Pé-de-Gigante, Brazil (21o37'30" S, 47o37'30" W). Sensor spectral responses were analysed, in the form of NDVI images from Ikonos-Multispectral, Landsat-TM e Terra-ASTER, Terra-MODIS. Two years data of seasonal variation in NDVI images were compared with meteorological data and LAI and phytossociological parameters obtained from 39 plots. The two year time series of fifteen days images were compared with climatologic parameters. A temporal series of nine Landsat-TM images and one Ikonos- Multispectral and one Terra-ASTER were compared with the field data. The structural parameter with the highest overall correlation coefficient was the cylindrical volume. The best correlation coefficient of NDVI and LAI were obtained to Ikonos and Aster images (r = 0,74). A two year temporal series NDVI images were correlated with meteorological data to identify the phase lag over the vegetation structural gradient. The seasonal phase lag variation was lower with less structurally heterogeneous canopy and higher with high floristically heterogeneous canopy. The final results were achieved by the theoretical models of the seasonal variation of the vegetation physiognomies, conditioned by the climate.

1. INTRODUCTION

The reflectance of the vegetation in the red depends on the present amount of clorofila in leves and the reflectance of the vegetation in the next infra-red ray, of the alive foliar structure. In this way, the IVDN has been mainly related with fitomassa foliar green, among others parameters of the vegetation. The vegetation indices are numerical models that relate the spectral reply of the vegetation with the density of vegetation for area, in sight of the antagonistic answers of the red and next infra-red ray.

The Cerrado vegetation is the most seasonal vegetation in São Paulo state and the measurement of seasonal dynamics by orbital remote sensors was the object of this study. Cerrado vegetation has a characteristic physiognomic gradient determined by the proportion of herbaceous and arboreal components. The objectives of the study were to derive a model for the relationship between the variation of spectral response of the sensors, climate, and phenology of Cerrado.

Amongst the spectral indices of vegetation, the IVDN (index of vegetation for normalized difference) is more widely used for the study of the continental vegetation. The first works with the IVDN presented correlation with biomass of agroecossistemas and homogeneous vegetations (Tucker, 1979; Anderson *et al*., 1993) and with the amount of water in the leaf (Tucker, 1980). The pioneering works in Brazil with the use of the IVDN had searched to evidence the existing correlations between fitomassa of the open pasture and the observed spectral reply in orbital level through indices of vegetation (Bitencourt-Pereira, 1986; Valeriano & Bitencourt-Pereira, 1988; Santos, 1988).

Particulary in Brazil, Bitencourt-Pereira (1986) and Santos (1988) had made a calibration of the vegetation index, respectively, with the cerrado stricto sensu (s.s.). and the campo cerrado of central plateaus of Brasil. The first author related green fitomass with the spectral signature gotten by the Landsat-MSS and with radiometry of field, and found coefficients of linear correlation of 0,94 and 0,96 respectively.

Beyond the biomass, the fraction of covering of the vegetation frequently was related to the IVDN (Jasinski, 1990), as much in opened savannahs (Larsson, 1993), as in denser forests (DeFries *et al*., 1997). Another parameter of the structure that frequently is associated with the IVDN is the index of foliar area (IAF), that it can be esteem with use of optic sensors, based in the fraction of light intercepted for the canopy (Chen 1996a and 1996b; White *et al*., 1998; Eklundh *et al*., 2001). Other parameters, as density and basal area, also are associates to this index. D'Arrigo *et al*. (2000) had related the annual variations of long temporal series of IVDN with growth´s rings of species of boreal forests.

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Some authors, to relate the parameters of the vegetation with the IVDN, or secular series of the index, had beyond pointed the importance of the quantification of the not structural parameters of the vegetation in the studies of ecological processes (Cihlar *et al*., 1991; Sellers *et al*., 1994; Chimitdorzhiev & Efremenko, 2000).

Since the first works of correlation of the parameters of the vegetation with the IVDN, the influence of the seasonal variations always it was considered. Generally, the authors use sensors high temporal resolution and low space resolution. In these works they are identified, in continental areas, the temporal variation of the IVDN (Tucker, 1986; He executes *et al*., 1991; Reed *et al*. 1994; Batista *et al*., 1997; Huete *et al*., 2002). In other cases, this seasonal variation of the IVDN is associated the parameters of the climate as the pluvial precipitation in African savannahs (Fuller & Prince, 1996) and in the Brazilian campo cerrado (França & Setzer, 1998). In some cases, the sazonais variations had been associates to the variations of the vegetative fenologia of the vegetal covering, for the determination of fenofases vegetative (Ludeke *et al*. 1996; Duchemin *et al*., 1999).

In Brazil, specifically in the Open pasture, already studies had been carried through relating the fenologia, with images IVDN and rain regimen, in fisionomias of campo limpo, campo cerrado (França & Setzer, 1998), cerrado stricto sensu and cerradão (Santos & Shimabukuro, 1993; Galvão *et al*., 1999), or considering all the physiognomic gradient (Bitencourt *et al*., 1997, Mesquita Jr, 1998).

The objective of this work is to quantify the relation between parameters of the structure of the fisionomias of Cerrado and images of orbital sensors. The decurrent limitations of the temporal and space variations will be considered. In such a way, 39 fixed parcels were sampled in the field land associeted with satellites images of the Terra-MODIS, Landsat-TM (30x30m), Terra-ASTER (15x15m), Ikonos-Multispectral (4x4m).

2. MATERIALS & METHODS

2.1 Study site

The study site was located in the Pé-de-Gigante (21o37'30" S, 47o37'30" W), part of Vassununga state park, in São Paulo state, Brazil (fig. 2). The altitude in the area varies from 590 to 720 meters, with average altitude of 675m and with 1225 ha of area. The predominance is of plain lands, with the situated parts steepest in the hillsides, in the limit of the microbasin of draining.

The Pé-de-Gigante is constituted by a gradient of fisionomias from campo cerrado (grass type) to cerradão (forest type). This configuration of physiognomic gradient was presented by Coutinho (1978), a part of the concept of Cerrado vegetation.

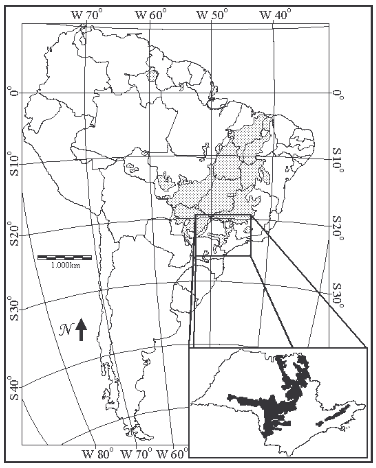

Figure 1. São Paulo state location in the South america, dark areas represent the Cerrado domain in São Paulo.

2.2 Methods

Inside of the study area, 39 fixed parcels were installed, diposed in 3 transects of 390 meters with 13 parcels of 30x30 meters each (fig. 2). The transects were apropriated located on a gradient of fisionomias, from campo cerrado (grassy) to cerradão (forest). On this sample plots fitossociological parameters of the vegetation were colected.

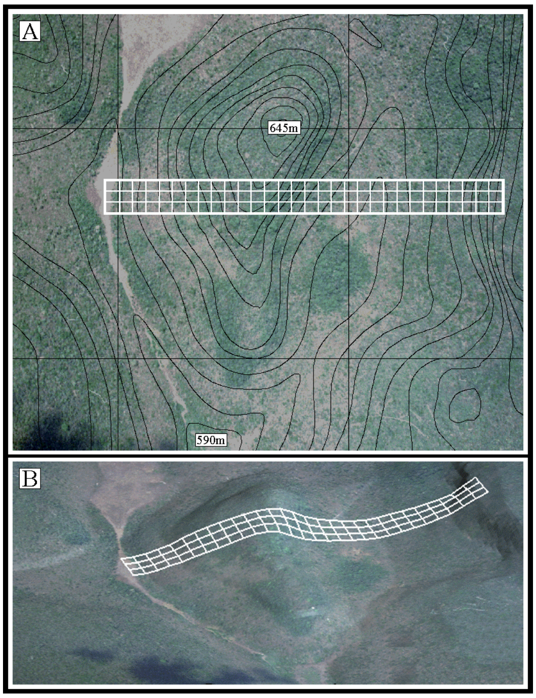

Figure 2. Position of the sample plots in the field over a 3D representition of the relief.

The initial point was found with the aid of GPS (UTM 23K, 227402E, 7605144N) had been transferred to a landmark of concrete in the place. From this point, from East was traced a line straight line in the direction to West, in relation to the geographic north.

Eleven images had been used for the calculation of the IVDN of the study area, being nine of the Landsat-TM, an image of the

Ikonos-Multispectral satellite and an image of sensor ASTER of the satellite Terra.

All the images had been geographically registered so that the cells of each image were coincident; also the possible geometric errors had been corrected, as well as, converted for physical values. Initially, the digital numbers had been converted for radiância and, later, converted for reflectance at satellite level (Robinove, 1982; Markham & Barker, 1986; Hill, 1991; Mesquita Jr. & Bitencourt, 1997). During the conversion for reflectance, the values of radiância are corrected to the illumination effect, caused for the relative position of the Sun. The images of each date had been transformed into IVDN images (Rouse *et al*. 1973) and were selected only the area of study inside of the Pé-de-Gigante.

In the sample plots of 30x30m were sampled the index of foliar area registered (IAF), with optic sensor LAI-2000/LiCor, in June of 2001 and January of 2002, when the percentages of covering of the projection of the coverege of the trees had been quantified, in each plot. The figure 3 showed IVDN images of the satellites: Landsat-TM, Terra-ASTER and Ikonos-Multispectral and the position of the 39 sample plots in the study area.

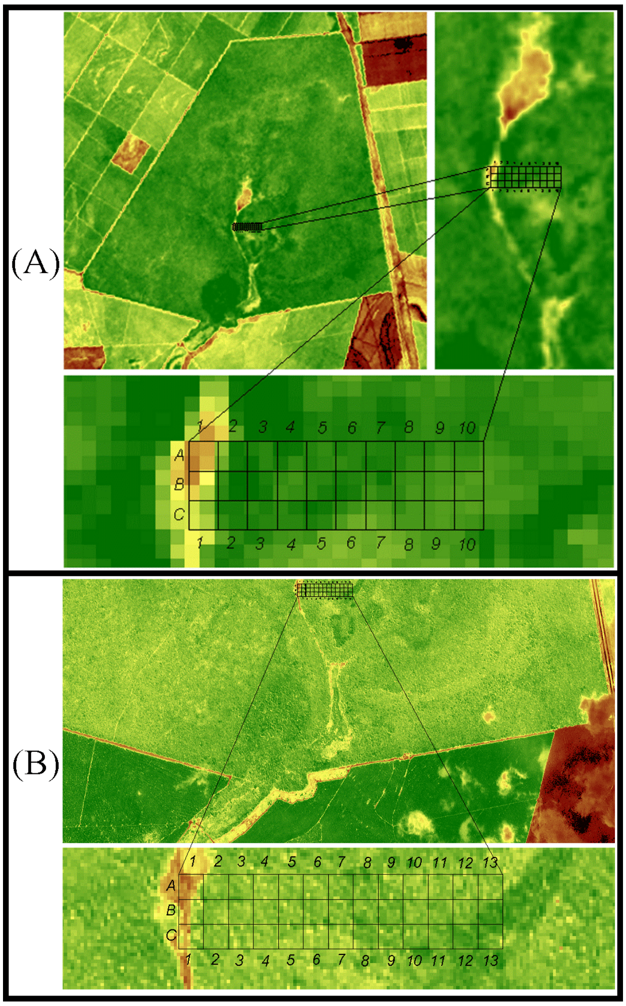

Figure 3. The sample plots position geografically associated with the Terra-ASTER and Multitemporal-Ikonos NDVI image.

3. RESULTS AND DISCUSSION

The available images and the following parameters of the vegetation had been carried through correlation analyses between the IVDN and: height, basal area, cronw area, density of individuals, vegetation cover, volume of the cronws, cylindrical volume, total volume and index of foliar area, of each parcel of 30x30m. In table 1, are presented the coefficients of correlation between the parameters and the IVDN. The parameters of the vegetation and images IVDN had been ordered in the table based on the coefficients of correlation, the greater for the minor, respectively, of the right for left and from top to bottom. The parameter that presented the best coefficients of correlation with all the images was the cylindrical volume, the image that presented the highest coefficients of correlation was the Landsat-TM image of September of 1994.

	Volume Cilíndrico (m^3)	Altura (m)	Área Basal (m^2)	Densidade de Indivíduos	Área Copa (m^2)	Cobertura (%)	Volume de Copas (m^3)	Volume total (m^3)	IAF	Total[1]
Landsat- **set/1994**	**0,82**	**0,89**	**0,80**	**0,82**	**0,88**	0,73	0,71	0,69	0,24	*6,58*
Landsat- **jul/1996**	0,79	0,84	**0,80**	0,80	0,86	**0,80**	0,73	0,74	0,37	*6,73*
Ikonos- **abr/2001**	0,67	0,69	**0,80**	0,80	0,61	0,40	**0,75**	**0,76**	**0,74**	*6,22*
Landsat- **set/2000**	0,76	0,80	0,72	0,73	0,81	0,78	0,61	0,62	0,25	*6,08*
Terra- **nov/2002**	0,47	0,43	0,62	0,58	0,41	0,14	0,59	0,61	0,74	*4,59*
Landsat- **ago/1995**	0,53	0,53	0,48	0,45	0,54	0,50	0,29	0,28	0,04	*3,64*
Landsat- **jun/1997**	0,42	0,49	0,39	0,44	0,44	0,40	0,30	0,28	0,22	*3,38*
Landsat- **nov/1995**	0,54	0,53	0,40	0,38	0,46	0,40	0,30	0,24	[-0,03]	*3,28*
Landsat- **jun/1995**	0,57	0,50	0,43	0,36	0,39	0,43	0,22	0,14	[-0,07]	*3,11*
Landsat- **jul/1995**	0,36	0,28	0,47	0,39	0,27	0,06	0,27	0,30	0,53	*2,93*
Landsat- **jan/1996**	0,39	0,27	0,22	0,11	0,15	0,22	0,00	[-0,07]	[-0,03]	*1,46*
Total[2]	*6,32*	*6,25*	*6,13*	*5,86*	*5,82*	*4,86*	*4,77*	*4,73*	*3,26*	

Ikonos-Multspectral of 2001 and the Landsat-TM images of September 1994 are distinguished of others, therefore they had had the maximum values for 4 parameters. The image of September of 1994, mainly with the parameters of the structure of the trunk, and the Multispectral-Ikonos of 2001, mainly with the structure of leves.

The gotten results had been similar to the results gotten in other works with Cerrado with Bitencourt-Pereira (1986) and Santos (1988). Although the amostral area has been relatively small for the Landsat-TM images, the gotten values of IVDN had been similar to the gotten ones for Mesquita Jr. (1998). The control of the taking of data in the field and the work multiscales, with the Terra-ASTER images and of the Ikonos-Multispectral, they make possible qualitative and quantitative profit of the relations between the parameters of the vegetation and the IVDN.

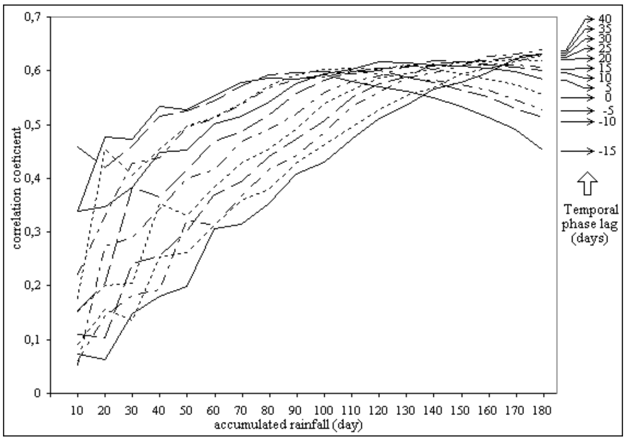

Figure 4. Correlation coeficients between Terra-MODIS NDVI images and total rainfall preciptation (mm).

The values of Terra-MODIS IVDN had been correlated with the amount of rains, the data used were supplied by the meteorological station of Santa Rita do Passa Quatro municipalty (C4-107, DAEE). Each point of the image was correlated with the precipitation accumulated in milliliters of rain, of 30 up to 360 previous days. Figure 4 are shown the graphically the averages of the correlation coefficient of each point of the image correlated with the pluvial precipitation.

For the conditions without temporal phase lag (equal zero), the curves had been gotten with approximately 120 days (4 months) of accumulated precipitation. However, if consider the temporal phase lag, the curve had been gotten with 360 and a positive displacement of the IVDN of 95 days. The variations of temporal phase are not equal during all the year. The coefficients of correlation and the respective displacements of phase in the period of daily before rain period and after-rainfall period are represented in figure 5.

The gotten results indicate that the relation between the field data and of the orbital sensors of the vegetation still are dependent of the integration between the sampling methods. In the case of the measures of IAF, an inverse relation between the space resolution and the coefficients of correlation exists, the best result had been gotten for the images of the Ikonos-Multispectral. This inverse relation already was noticed by other authors (White *et al*., 1998). Still related to the sampling, another problem is that it deserves to be investigated the depthness of the crown and its structure in the interior of the crown of the trees.

Beyond the structural problems, would be necessary methods of sampling of the vegetative fenologia of the arboreal species, including its relations with lianas and epifts. The effect of the epifts already had been studied in barren vegetations (Karnieli *et al*., 1996). Beyond these effect, the burlap can influence the IVDN in the dry periods (vanLeeuwen & Huete, 1996).

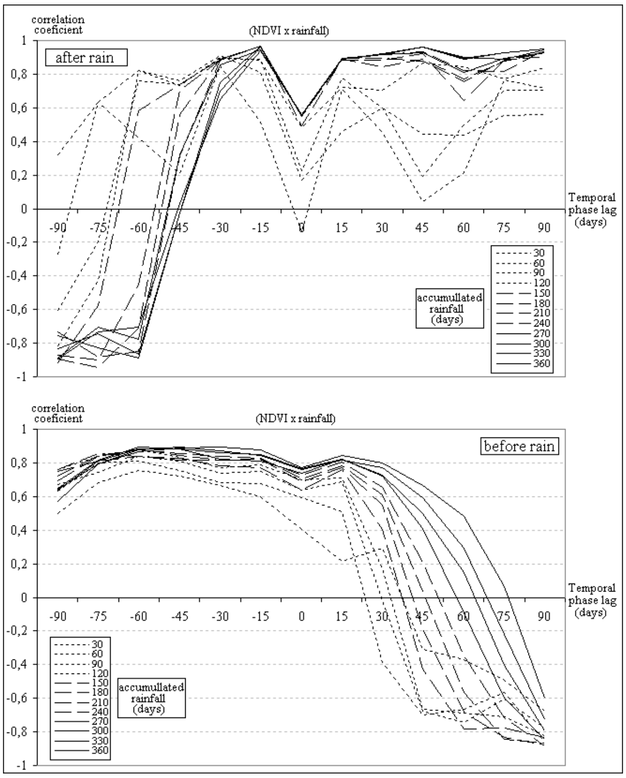

Figure 5. Correlation coeficients between Terra-MODIS NDVI images and total rainfall preciptation (mm).

4. CONCLUSIONS

In this work it was possible to establish, of quantitative form, the relations between the more important climatic factors in the seasonal variation of the IVDN gotten for orbital images. It was possible to define the maximum and minimum intervals of IVDN in conditions where probably the hidric availability and fotoperíodo had been more important to the sazonal variation. The cases of low extreme temperatures had a effect of reduction of the values of IVDN of the grass physiognomies. The effect of the low temperatures will be sharper in the beginning of the dry period and diminish gradually with elapsing of this period. Some difficulties had been identified to correlate parameters of the vegetation and the spectral indices of vegetation. This due to, mainly, to the characteristics of the methods and the absence of investigation about the characterization of the structure of leaves in the interior of the cronw that compose the vegetal covering. The results of this work can serve to the global estimates of parameters of the vegetation using the IVDN, being of basic importance to consider the fenologia of each Cerrado physiognomies and as well as its seasonal variation.

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6. ACKNOWLEDGEMENTS

I would like to thank to the Dr. Getúlio Teixeira Batista who borrow me the LAI-2000/Li-Cor equipment. To thank NASA (National Agency of Space and Aeronautics), through the EOS-DIS (Earth Observing System - Date and Information System), for allow the use of satellite images of MODIS and ASTER used in this work. I wish to thank the Dr. Tomoaki Miura and the Dr. Afredo Huete for the initial tips on acquisition and processing of MODIS images. Dr. Humberto Ribeiro da Rocha to allow me the use of Ikonos-Multispectral image, through accord with NASA, project LBA (Large Scale Biosphere Atmosphere relationship). The University of São Paulo and Universidade de Edimburgo where the works had been developed. The special thanks to BIOTA/FAPESP that supported the development of this work.