

## PCA used to discriminate phenological variations in Cerrado physiognomy, in São Paulo – Brazil.

Marisa Dantas BITENCOURT

LEPaC – Dept of General Ecology - Biosciences Institute – University of São Paulo  
Rua do Matão, travessa # 14, 321 – CEP 05508-900 – São Paulo-SP, Brasil.  
tencourt@ib.usp.br

**KEY WORDS:** standard PCA, NDVI, Cerrado, seasonal variation.

### 1.1 ABSTRACT

The Cerrado Biogeographic Province in Brazil, which occupies around 18% of the national territory, is the ecosystem in more danger of disappearing as a result of agriculture frontiers. Their landscape structure is a gradient of density, height, woody and herbaceous species, resulting in at least five physiognomies, ranging from grassland to forest. The climate where the Cerrado occurs present two distinct periods: a dry one from June to September and a rainy one from October to May. Because of that seasonal variation and that physiognomic patchwork it is very difficult their identification and their quantification. During the dry period the herbaceous stratum become more and more dried. The woody species, on the other hand, tend to loose their greenness a little bit further, since it can get water from deeper supplies. The results are exactly what is noticeable through NDVI, i.e., a strong greenness response after the rain: from June/95 to July/95, the *Cerrado s.s.* physiognomy gained 31.5 hectares of greenness, lost 32.2 hectares, and 534.96 hectares remain the same (NDVI interval remain exactly the same – varying from zero to 0.46); from July/95 to August/95, gained 14.3 hectares of greenness, lost 23.4 hectares, and 560.97 hectares remain the same (NDVI interval change from 0 - 0.46 to 0 - 0.43); from August/95 to November/95, gained 63.09 hectares of greenness; lost 8.55 hectares and 527.04 hectares remain the same (NDVI interval change from 0 - 0.43 to 0.0252 - 0.43); and from November/95 to January/96, gained 184.5 hectares of greenness; lost 1.08 hectares and 413.1 hectares remain the same (NDVI interval change from 0 - 0.0252 to 0.01852 - 0.59).

### 1. INTRODUCTION

The flora of the cerrado consists of approximately 800 species of trees and large number of shrubs with many herbs and subshrubs as well. It has typical features of pyrophytic savanna vegetation. The trees are of low contorted form with thick, corky, fire-resistant bark. Sclerophylly is common: many leaves have thick cuticles, sunken stomats, greaty lignified and sometime silified tissues. Xylopodia are well developed in both the woody and herbaceous vegetation (Furley, 1994 and 1996; Furley et al. 1992; Furley and Ratter 1988; Ratter and Dargie 1992; Ratter *et al.* 1996).

According to Coutinho (1978), the term *cerrado sensu lato* (*cerrado s.l.*) covers the range of savanna physiognomies, from grassland to arboreal types of vegetation. This will depend upon the stage that has been reached in the continual process of ecological readjustment to achieve 'equilibrium'. Such a concept of ecological equilibrium varies according to soil type and water supply, and can be grouped into five principal physiognomic structures: Campo Limpo, Campo Sujo, Campo Cerrado, Cerrado s.s. and Cerradão, respectively. The ecological optimum of each physiognomy is strongly dependent of soil type and water supply (Sarmiento, 1992), and can be grouped into five principal physiognomic structures: *Campo Limpo*, *Campo Sujo*, *Campo Cerrado*, *Cerrado strictus sensus (s.s.)* and *Cerradão*.

The complexity of the *Cerrado* physiognomies and their seasonal variations are responsible for many misclassification, not only in the field but also when orbital remote sensing is used. The reason for that misclassification is the leaves lost, during the dry period, and the new leaves offspring, during the rainy period, which strongly change the spectral responses registered by remote sensors, in the visible and infrared bands. Several attempts have been made to correctly identify those physiognomies using satellite images especially using vegetation indices.

The red band shows the chlorophyll concentration, the near infrared band shows the green leaves density and the middle infrared shows the leaf water contents. The combination of red and near infrared bands in NDVI (normalized difference vegetation index), has been appointed as a good remote detector of several vegetation parameters and has

shown to be useful to analyze crops and natural vegetation covers. Choudhury (1987) had presented the sensitivity model to understanding of the relationship between vegetation indices and radiation absorption and net photosynthesis. shown the relationship between NDVI and canopy physiology by analyzing photosynthesis efficiency along all a day for sunflowers. Approaches were done to account the relation between NDVI and photosynthetic active radiation) and had notice the influences of the background spectral reflectance on this relation. The follow researches were conduct with application of NDVI to vegetation analysis (Wiengand *et al.* 1991). Gamon *et alii* (1995) demonstrate the use of NDVI to analyze three physiognomic types of Californian vegetation by relating NDVI, canopy structure, and photosynthetic activity.

In Brazil, several attempts have been made to understand the relationship between the orbital reflectance (red and near infrared spectral bands) and the green biomass measured on the field. Bitencourt-Pereira (1986) analyzed the correlation between spectral data from Landsat MSS and field radiometer, with green biomass of Campo Cerrado physiognomy, by clipping method (measure fresh and dried biomass). Thus we can say that NDVI shows indeed a high relationship between phytomass of the Brazilian savanna or Cerrado.

According to Eastman & Fulk (1993), the standardized PC2 is the most prevalent element of variability in NDVI – normalized difference vegetation index. According to Chavez & MacKinnon (1994), Standard PCA indicates temporal contrast if two bands of different dates are used as input. Thus, by properly classifying the PC2 image it is possible to make a seasonal analysis identifying where greenness is lost, maintained or gained, from one date to another. NDVI is been accepted as an indicator of green vegetation density all over the world and vary from -1 to 1.

Mesquita Jr. (1998) mapped the probable area of each physiognomy to occur in a Conservation Unit Area located in the state of São Paulo-Brazil. He uses images of two extreme seasonal conditions and found four physiognomies there: i) *Cerrado s.s* (area of 599,65 hectares); ii) transition from *Cerrado s.s* to *Cerradão* (area of 404,54 hectares); iii) *Cerradão* (area of 49,11 hectares); and iv) *Campo cerrado* (area of 114,14 hectares).

Thus, using Mesquita Jr. (1998) physiognomy class *Cerrado s.s*. (strictu sensus) I test the ability of PC2 of near infrared in estimating greenness, using TM-LANDSAT image (TM-4) of five cloud free dates.

## 2. MATERIAL AND METHODS

The study area is a conservation unit named Pé-de-Gigante with 1225 hectares of area, created in 1970. The vegetation comprises cerrado's physiognomies, one little spot of Semideciduous Seasonal Forest and, along the stream, Riparian Forest in degraded state. The reserve is located in the city of Santa Rita do Passa Quatro - SP (47°37'W; 21°37'S). Considering the regional scale the site is located on southern edge of Cerrado Domain .

The relief is moderately flat with altitudes ranging from 590m to 740m which contains Paulicéia's stream head. The region substrate is geologically formed by alluvial erosion of arenitic formations of Pirambóia and Botucatu. The deposition of sediments resulted poor soils, close to the stream the soil is poorer. This configuration is covered by different physiognomies, vegetation comprises grassy, shrubby, savanna and arboreal cerrado types. This figure show the ecotonal gradients, proposed by Coutinho (1978), ranging from absolute herbaceous component to absolute arboreal component, and within intermediate forms, with different rates of one component in detriment of another.

In the study area the cerrado landscape vary from grassy to arboreal physiognomies, i.e., from *campo cerrado* to *cerrado stricto sensu*, and finishing on *cerradão*.

Climatically the region is classified as a tropical seasonal with wet summer and dry winter which correspond to Cwa of Koeppen's Climatic Classification (1948). The climatic diagram (Walter 1955), show the seasonal distribution of the rainfall along the year. Mean annual precipitation is 1475mm year<sup>-1</sup> and mean monthly temperature is around 23°C with small variation, but mean daily variation is about 20°C.

Thus, a time series evaluation, using standardized Principal Components Analysis (PCA), with TM-4 images from June/1995 to January/1996 were performed in order to identify which area gain greenness first. The resulting images were classified in three classes: low red reflectance variance, no variance, and high reflectance variance.

Each standard PC2 image of each combination pair were classified in three significant intervals (X, Y, and Z), result into three classes: a)  $-2sd < X < -sd$ ; b)  $-sd < Y < +sd$ ; and c)  $+sd < Z < +2sd$  (sd = standard deviation). Because near infrared reflectance is directly proportional to green leaves density, the class "a" correspond to the pixels with less

reduction in the reflectance which correspond to *gain* of greenness; class “b” to no change in the reflectance which correspond to its *maintenance*; and class “c” to more reduction in the reflectance, which correspond to its *loss*.

### 3. RESULTS AND DISCUSSION

The precipitation condition in those dates were: JUN95 = almost nothing; JUL95 = mean of 50 mm; AGO95 = almost nothing; NOV95 = October's mean = 300 mm; and JAN96 = rainy period. To test the hypotheses I choose the physiognomy *Cerrado s.s.* to make four PCA combinations: I) JUN95–JUL95; II) JUL95–AGO95; III) AGO95–NOV95; and IV) NOV95–JAN96.

The *Cerrado s.s.* greenness is spatially distributed in the **Figure 1 (I, II, III and IV)** with each NDVI interval:

- from June/95 to July/95, NDVI interval change from 0 - 0.46 to 0 – 0.43 to 0.46 (Fig. 1- I).
- from July/95 to August/95, NDVI interval change from 0 - 0.46 to 0 – 0.43 (Fig. 1 - II).
- from August/95 to November/95, NDVI interval change from 0 – 0.43 to 0.0252 – 0.43 (Fig. 1 – III).
- from November/95 to January/96, NDVI interval change from 0 - 0.0252 to 0.01852 – 0.59 (Fig. 1 – IV).

The area variation are presented on **Table 1** which corroborate the expected, e.i., from dry to rainy whether condition the vegetation greenness of the *Cerrado s.s.* increases.

Table 1 – The greenness area variation from June/95 to January/96.

Period	Gain (hectare)	Lost (hectare)	Remain the same (hectare)
June/July 1995	31.50	32.2	534.96
July/August 1995	14.30	23.4	560.97
August/November 1995	63.09	8.55	527.04
November-96/January-96	184.50	1.08	413.10

### 4. CONCLUSIONS

The experience with the *Cerrado s.s.* suggest that the PC2 of the same band with different date can be useful to estimate greenness of other physiognomies of the same biome.

### 5. REFERENCIAS

- Bitencourt-Pereira, M.D.; 1986 - **Correlação de fitomassa foliar de Campo Cerrado com dados espectrais obtidos pelo sistema MSS-LANDSAT e por radiometria de campo.** São José dos Campos, 90 p. INPE-3747-TDI-203
- Chavez, P.S.; MacKinnon, D.J. 1994 - Automatic Detection of Vegetation changes in the Southwestern United States Using Remotely Sensed Images. *Photogrammetric Engineering & Remote Sensing*, 60(5):571-583.
- Choudhury, B.J. 1987 - Relationships Between Vegetation Indices, Radiation Absorption, and Net Photosynthesis Evaluated by Sensitivity Analysis. **Remote Sensing of Environment**. Vol. 22, pp. 209-233. Elsevier Science Publishing Co. Inc., New York.
- Coutinho, L.M 1978) - O conceito de cerrado. *Revista Brasileira de Botânica*, 1:17-23.
- Coutinho, L.M. 1990. O cerrado e a ecologia do fogo. **Ciência Hoje**, 12(88):22-30.
- Eastman, J.R.; Fulk, M. 1993 – Long Sequence Time Series Evaluation Using Standardized Principal Components. *Photogrammetric Engineering & Remote Sensing*, 59(6):991-996.
- Furley, P.A.; Proctor, J.; Ratter, J.A. (eds.); 1992 – **Nature and Dynamics of Forest-Savanna Boundaries**. Chapman & Hall, London.

- 
- Furley, P.A. (1994) - Savanna formations: ecology and environment. *Progress in Physical Geography*, 18(2):276-294.
- Furley, P.A. (1996) - The influence of Slope on the Nature and Distribution of Soils and Plant Communities in the Central Brazilian *cerrado*. In: M.G. ANDERSON and S.M. BROOKS (Eds) *Advances in Hillslope Processes*, volume 1, John Wiley & Sons Ltd.
- Furley, P.A.; Ratter, J.A. (1988) - Soil resources and plant communities of central Brazilian cerrado and their development. *Journal of Biogeography*, 15:97-108.
- Furley, P.A.; Ratter, J.A. (1990) -The nature of the forest-savanna boundary on Maraca Island, Roraima. *Geographical Journal*, 156():251-266.
- Gamon, J.A.; Field, C.B.; Goulden, M.L.; Griffin, K.L.; Hartley, A.E.; Joel, G.; Peñuelas, J.; Valentini, R.; 1995 - Relationships between NDVI, canopy structure, and photosynthesis in three Californian vegetation types. **Ecological Applications**, 5(1):28-41. Ecological Society of America.
- Mesquita Jr., H.N. 1998 – Análise temporal com sensor orbital de unidades fisionômicas de cerrado, na Gleba Pé-de-Gigante (Parque Estadual de Vassununga – SP) – Dissertation at General Ecology Department – University of São Paulo – March 1998. 118 p.p.
- Ratter, J.A.; Bridgewater, S.; Atkinson, R.; Ribeiro, J.F. (1996) Analysis of the floristic composition of the Brazilian Cerrado vegetation II: Comparison of the woody vegetation of 98 areas. *Edinburgh Journal of Botany*, 53(2):153-180.
- Ratter, J.A.; Dargie, T.C.D. (1992) - Analysis of the floristic composition of 26 cerrado areas in Brazil. *Edinburgh Journal of Botany*, 49(2), 235-250.
- Sarmiento, G.; 1992 - A conceptual model relating environmental factors and vegetation formations in the lowlands of tropical South America. In: FURLEY, P.A.; PROCTOR, J.; RATTER, J.A. (eds.); 1992 – **Nature and Dynamics of Forest-Savanna Boundaries**. Chapman & Hall, London.
- Wiengand, C. L.; Richardson, A.J.; Escobar, D.E.; Gerbermann A.H.; 1991 – Vegetation Indices in Crop Assessments. **Remote Sensing Environment**, 35: 105-119. Elsevier Science Publishing Co. Inc, New York.

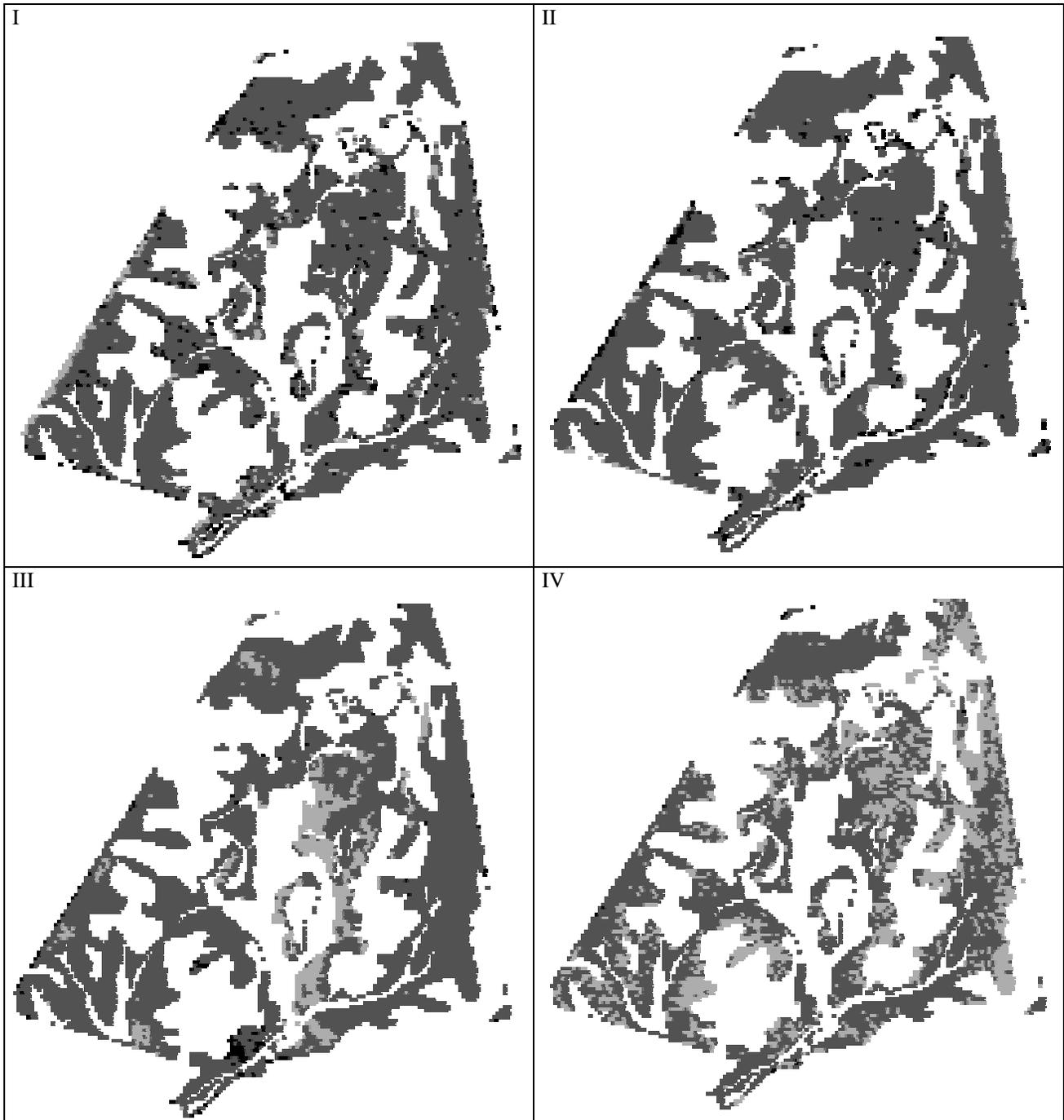


Figure 1 – I) JUN95–JUL95; II) JUL95–AGO95; III) AGO95–NOV95; and IV) NOV95–JAN96, where Dark = **loss** , Medium gray = **maintenance**, and Light gray = **gain green biomass** .