Anais XIII Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis, Brasil, 21-26 abril 2007, INPE, p. 4493-4500.

Application of vegetation index to assess fire risk in open grasslands with predominance of cespitous grasses in the Nhecolândia sub-region of the Pantanal

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Abstract – the aim of this paper was to evaluate the relationship between fuel proprieties of two open grasslands with predominance of cespitous grasses and NDVI values obtained from CYBERS images in the dry season of two consecutives years (2005 and 2006), in the Nhecolandia sub-region, Pantanal. In the image processing, the ENVI 4.2 and ArcView programs were used. The characteristic of the vegetation were plotted and subjected to regression analyses. On the appraised characteristics, only green phytomass and dead plant moisture presented moderate association. As these characteristics are related to fire danger, the data of NDVI can indicate the fire danger, since other factors are considered, such as climatic variables, soil humidity and distribution/continuation of fuels (phytophysionomy).

Palavras-chave: index vegetation, fire risk, Pantanal, índice de vegetação, risco de fogo, Pantanal.

1. Introduction

In the Pantanal, the rural producers make use of the controlled burning annually for cleaning and renewal of native pasture, usually in the open grassland areas, with predominance of cespitous grasses, known as “macegas”, such as “capim-carona” (*Elyonurus muticus*), “capim-vermelho” (*Andropogon hypogynus*), “fura-bucho” (*Paspalum lineare*), among others. As these species forages curing quickly, they lose its quality, causing decrease of the intake by cattle. As consequence, there is a formation of extensive areas of "macegas" (Santos et al., 2005), that constitute in great amount of fibrous and highly inflammable combustible material, especially in the end of the dry period (August and September). Annually, fires are registered in the area of the Pantanal, and its intensity is directly associated to climatic conditions. Although, in the literature, there are several indexes of forecast of fire risk, especially those involving climatic variables. However, there are still no specific studies of forecast for the Pantanal region.

The decisive factors for a fire to start are the combustible material, the climatic variables, and the topography. There are several available techniques to evaluate the topographical and meteorological variables in large scale, however, the identification, location, and fuels properties are more difficult because of the high spatial and temporal variability, especially in a dynamic and complex area as the Pantanal. The properties of the fuels involve the type, phytomass, condition and humidity, among which the moisture content is the most important for fire control (Dennison et al., 2000). An attempt that is being globally implemented is the development of fire risk prediction systems through technologies of remote sensing, which informs the vegetation conditions in large scale (Hardy and Burgan, 1999). One of the vegetation indexes is the well- known normalized difference vegetation index (NDVI), expressed by the reason among the difference of the reflectance measure of the near infrared (NIR) channels and red (R) and the sum of those channels whose values depend, among other factor, on intrinsic aspects of the vegetation (architecture, density and humidity) and soil (humidity, texture and iron oxid). NDVI values vary from -1 to 1. In any way, the value of NDVI next to 1 is associated with dense and green vegetation coverings, while low values is associated with dry vegetation.

The objective of this work was to evaluate the relationship between fuel characteristics of two open grasslands areas with predominance of cespitous grasses and values of NDVI obtained from images of CBERS for two years, 2005 and 2006, in the drought period, in the Nhecolandia sub-region of the Pantanal.

2. Material and Methods

The experimental area was the sub-area of Nhecolandia, characterized by the presence of a mosaic of units in the landscape, constituted of "cordilheiras", savannah fields, open grassland, ponds and temporary channels. According to Köppen, the climate of the area is classified as type Aw, a tropical megatermic, with the medium temperature that's over 18°C at the coldest month, with dry winter and rains in the summer. The annual averages of precipitation, temperature and relative humidity of the air, in the period of 1977-2001, were 1.181,0 mm, 25.4°C and 81.3%, respectively (Soriano and Alves, 2005).

The relief is plane, with the altitude around 90 m above the sea level (Ratter et al. 1988) and presenting small unleavened areas (up to 3 m) among the phytophysionomys. The floods do not occur with uniformity in the whole plain, there're some areas that are permanently flooded, other areas are flooded for a long period (above 6 months), while the great part of the Pantanal has floods for a short periods (under 6 months). In areas with savanna predominance, pluvial flooding is very common and, in specific areas, a flood of fluvial origin is proceeded. Both the pluvial flooding and the flood of the fluvial origin are not uniform in a local scale since gradients in the personal micro-relief (from 0 to 2 m) propitiate an intrinsic mosaic of situations that influences the biotic patterns. The dynamics is then marked by a pulse of variable flood in function of the pluviosity and place inside Pantanal. The precipitation data and relative humidity from the two years are shown in **Figure 1**.

Open grassland areas were selected with predominance of "capim-carona" (*E. muticus*) and "capim-vermelho" (*A. hypogynus*), being six in August of 2005 (three areas of "capim-vermelho" and three areas of "capim-carona") and 12 in August of 2006 (six area of "capim-vermelho" and six areas of "capim-carona"). In each of the areas, the're allocated randomly about 20 squared samples of $1m^2$, in which there were appraised some characteristics of the vegetation: pasture height, ground cover percentage and of the grassland predominant cover percentage. In all the squares, the vegetation was cut height on soil surface. After the material was weighed (total fresh phytomass) and soon afterwards made the manual separation and weighting of the material senescent (dead fresh phytomass) and of the green material (green fresh phytomass). The bulk density was estimated by the division of the total phytomass and by the height of the foliage. The calculations of the plant moisture and dead fresh phytomass were made by dividing the difference of weight estimated in camp by fresh weight in greenhouse to 65°C.

Images of the CBERS satellite (Bell-Brazilian Satellite of Terrestrial Resources) were downloaded from the Internet, Sensor CCD, orbit/point 166/121, in closer periods of the date of collection of field data, were acquired by DGI/INPE (August 2005 and 2006). The images of both years were georeference with base in the images of MrSID (NASA).

The classes of NDVI, estimated through the **Formula 1,** were defined for the georeference points of the studied areas in the two satellite images. Ranges of NDVI were estimated for the other phytophysionmic of the Pantanal, with the aid of thematic map, considering “cordilheiras”; savannas; open grasslands with predominance of "caronal" and “capim-vermelho”, more humid and drier seasonal wetland and aquatic vegetation/aquatic presence.

$$NDVI = (\text{band } 4 - \text{band } 3) / (\text{band } 4 + \text{band } 3) \quad (\mathbf{1})$$

Different equations of simple linear regression were adjusted as independent variable NDVI, and as dependent variables, total fresh phytomass, dead fresh phytomass, green fresh phytomass, bulk density, total dry phytomass, total plant moisture, dead plant moisture and grassland cover. The least square method was used to estimate the dependent variables in function of NDVI in agreement with the methodology described by Lapponi (2000), using the Excel program.

3. Results and Discussion

Although NDVI is greatly used in the evaluation of the phenology and productivity of the vegetation, the correct interpretation of the values of NDVI is not easily elaborated, due to interactions among vegetation, climate and hydrological properties of the soils. As an integrated indicator of the vegetation, NDVI is associated with density of the covering, photosynthesis and humidity of the soil, in different way for each type of vegetation covering. Besides, it is not very clear which are the variables highly related with NDVI in certain time and period of time for certain place. In this study, comparing the range of variation of NDVI of the six appraised initial areas in 2005 (0.391304 to 0.417219) with the range of variation of 2006 of the same areas (0.354839 to 0.420690), it was noted a larger variation width in 2006, this may probably due to the climatic conditions, that influenced the soils properties and the vegetation. In Figure 1, the precipitation data and relative humidity of the air in 2005 and 2006 (until September) are shown and compared with the normal climatological of 26 years of the climatological station of the Nhumirim farm of Embrapa Pantanal, Nhecolandia sub-region, MS.

It was verified that rain quantity and distribution were very irregular through the years, when compared with normal climatological. Rains were better distributed in 2006 than in 2005, before the dry period. As for the values of relative air humidity it showed the same tendency of the normal, emphasizing smaller values in the critical months of the drought, from June to September, above all in August.

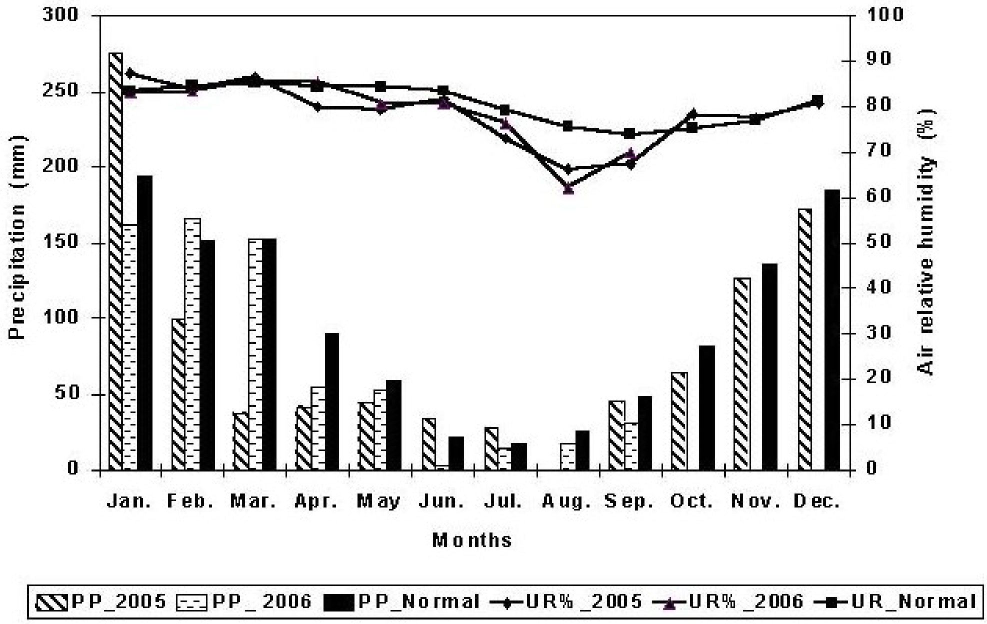

Figure 1 – Precipitation (PP) and humidity of the air (UR) in 2005 and 2006, compared with the climatological normal, Nhecolândia sub-region, Pantanal.

With the largest number of areas of samplings in 2006, it was observed a larger variation of the values of NDVI, where as the smaller value was 0.23 to "capim-vermelho" point sample (**Figure 2**), located in extensive flooded areas, that during the collection period, August of 2006, still presented a certain humidity in the soil. In general, in the interpretation of images of NDVI, the clearer ash tones indicate high vegetation indexes, while the darkest levels indicate lower index of vegetation, exposed soil and water. It was observed in the point sample (pixel) that the ash levels are darker; however, it doesn't necessarily represent low vegetation index and yes, presence of humidity. These interactions reflected in the relationship of NDVI with total dry phytomass, where value of R^2 were relatively low (0.31). According to Churkina et al. (2006) the hidric balance and the physical properties of the soil are the main parameters associated with the values of NDVI, it varies in function of the monthly precipitation that causes larger or smaller retention of water in the soil. **Table 1** consists of regression equations for the characteristics of the open grasslands areas ("macegas") appraised for two years, in drought periods. In the regression analysis for the communities in separate, a better relationship was observed for the other variables, indicating phytophysionomy interactions. Open grasslands with dominance of "capim-carona" did not present marked soil humidity, because these areas are generally free from inundation.

Table 1 – Regression Equations, determination coefficient (R^2), erro-pattern (EP) and value of the F test for the fuel characteristics of open grasslands with predominance and "capim-carona" and "capim-vermelho" in the dry period of 2005 and 2006, in the Nhecolandia sub-region, Pantanal, MS.

Fuel characteristics	Adjusted equation	R^2	EP	F	p
Total fresh phytomass	y = 420.55 + 3214.43x	0.20	710.0	0.63	0.440ns
Dead fresh phytomass	y = 63.47 + 6031.15x	0.25	1050.6	1.01	0.331ns
Green fresh phytomass	y = – 6739.02 + 21591.08x	0.52	653.3	4.93	0.045*
Bulk density	y = 6.13 + 174.65x	0.31	24.01	1.62	0.222ns
Total dry phytomass	y = 475.36 + 9278.60x	0.31	1305.1	1.55	0.232ns
Total plant mixture content	y = 57.80 – 68.64x	0.43	6.4	3.51	0.080ns
Dead plant moisture content	y = 41.92 – 67.08x	0.57	4.4	7.22	0.017*
Grasses cover	y = 97.2 – 80.76x	0.38	9.08	2.36	0.147ns

* p <0.05; ns= not significative

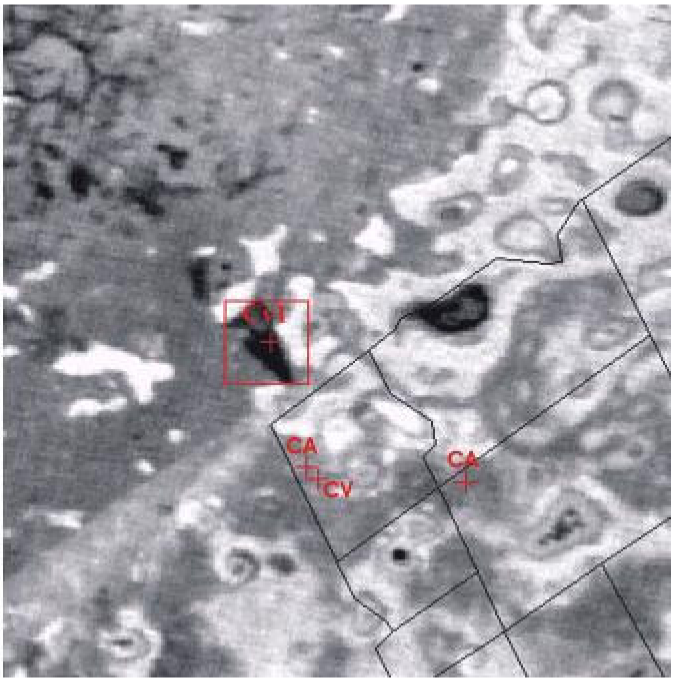

Figure 2 – Image of NDVI of Nhecolandia sub-region of the Pantanal captured by CCD/CYBERS satellite, in August of 2006. Cv = open grassland with predominance of "capim-vermelho", where the darker point sample (Cv1) indicates larger soil humidity, presenting lower value of NDVI (0.23); CA = open grassland with dominance of "capim-carona".

In the appraised periods, it was observed that characteristics such as: fresh green phytomass and dead plant moisture presented larger values of R^2 (**Figure 3**). Considering the percentage of dead plant mixture represents the mixture of extinction, that is the humidity in which fire doesn't disperse or the one that ceases (it extinguishes) the process of its burn, the values of NDVI of those areas of field of cespitous grasses can indicate the fire danger. Therefore, as the measurement of NDVI on this field areas increases, the levels of moisture of the dead fuel decreases while the levels of green phytomass increases, corroborating with the information in the literature, where NDVI represents the vigor of the vegetation. However, the values of NDVI seemed not to depend only on the vigor of the vegetation (**Figure 2**), this may probably be influenced by the humidity of the soil. According to Dennison et al. (2006), while the dead fuel depends on the humidity of the air to enter into balance, the humidity of the live fuels depends on several factors, as plant species, the health of the vegetation and the availability of water in the soil.

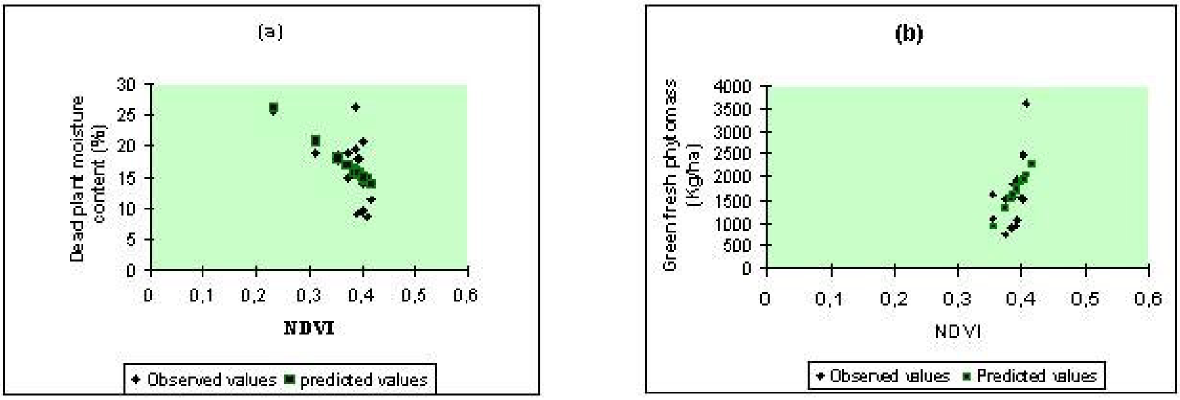

Figure 3 – Relationships between NDVI, dead plant moisture (a) and green fresh phytomass (b) of open grasslands with predominance of cespitous grasses, Nhecolandia sub-region, Pantanal, MS.

There are a few studies in the literature about the correlation between water content of the leaf and spectral reflectance. There is a divergence in the answers, because the reduction of the chlorophyll with the cure of the pasture that increases reflectance of the pasture, with consequent reduction of NDVI, but in turns, the decline of the water reduces the reflectance, with consequent increase of NDVI. Therefore, the visible band seems not to have enough sensibility to estimate the content of leaf water in absolute terms. Besides, humidity of the soil has been showing that it can affect the state of the culture and productivity potential more directly than the climatic variables (Adegoke et al., 2002). According to Chuvieco et al. (2004), the best variable related with the fuel moisture content was the relationship between NDVI and temperature of the surface (NDVI/TS).

In this study, the values of NDVI (0.39 to 0.42) obtained in the areas of cespitous grasses in the end of the dry period of 2005 can be considered as an indicative of high fire danger, because this was one of the years with larger number of fire focuses in the area and with medium temperature above the normal (Onigemo et al., 2006). According to NASA (Schindell, 2006), the year of 2005 was probably, the hottest year since 1890. Besides this, one week after the collection of the field sample, data that happened an accidental fire in the study area. However, the interpretation of the data of NDVI should not be made in an isolated way and yes associated with the local variables climatic, especially distribution of the precipitation, phytophysionomy types, humidity of the soil, among other factors. In **Figure 4**, it is shown the image of vegetation index generated in August of 2005, that should be considered as reference for the estimate of values of NDVI considered of high risk, especially for the most critical phytophysionomy, such as open grassland of cespitous grasses, savanna, dirty field and "cordilheiras". It is observed that these areas are disposed in mosaic pattern and interlinked, and that depending on the proportion of phytophysionomy more critical, larger cares should be taken in the fire prevention.

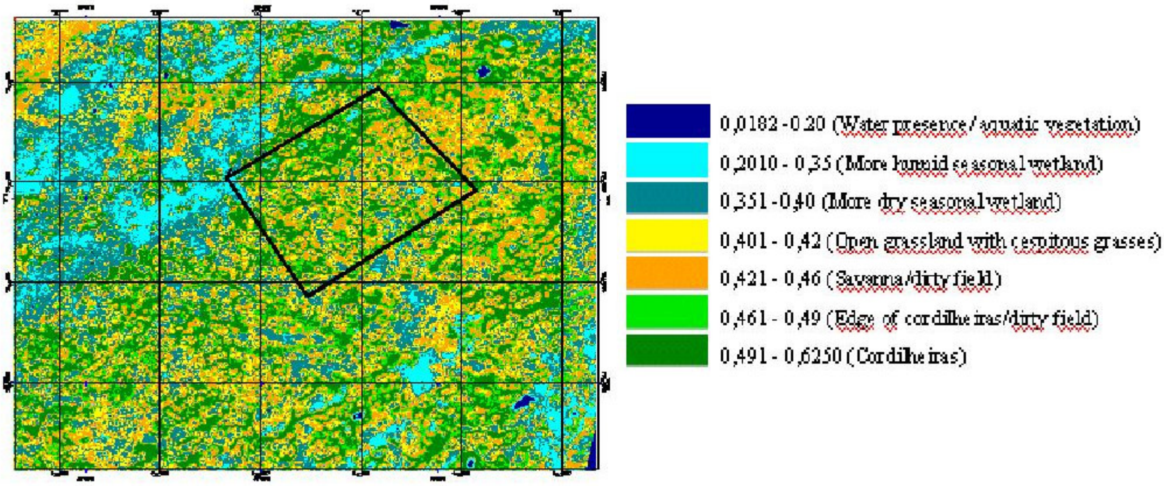

Figure 4 – NDVI image of the Nhecolandia sub-region, Pantanal, showing the ranges of NDVI values obtained in August of 2005, in function of phytophysionomy classes. In the image, it was observed the Nhumrim farm (black polygon) and the distribution of the open grassland with cespitous grasses, with NDVI values from 0.401 to 0.42.

4. Conclusions

The values of NDVI obtained through images at the peak of drought were related to the content moisture and fresh phytomass, showing its potential to estimate fire risk to the Pantanal. Additional studies area necessary for evaluation of NDVI in temporary series associated with climatic conditions, humidity of the soil and the continuation/distribution of the types of fuels (phytophysionomies), being possible to define indexes of forecast of fires for the Pantanal.

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