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Biophysical parameters analysis in the detection of coverage changes and land use in a conservation unit in the Brazilian Pantanal

In order to preserve the Private Reserve of SESC Pantanal Natural Heritage (RPPN) was established in 1997. The physiognomies there show rapid transitions, which makes it difficult to classify land use and complex dynamics of the flood regime. Therefore, the object of this work was to evaluate the temperature dynamics and biophysical parameters in a reserve in the Brazilian Pantanal. Precipitation data and images from the Landsat 5 satellite were used to compute biophysical parameters. Our results demonstrate that the largest area is occupied by shrubby vegetation, followed by pasture, cambarazal and murundus fields. The albedo, the surface temperature, and the NDVI showed significant differences over the studied period and in the dry and rainy seasons. The vegetation indices showed the highest values in the years of 1989 during the rainy season, while the highest values of albedo and surface temperature were obtained a decade later, periods that precede the formation and expansion of the RPPN SESC-Pantanal. The LAI did not show any significant difference between the entire period studied and between the dry and rainy seasons, which demonstrates that most of the vegetation maintained during the period of formation, expansion and preservation of the RPPN.

Keywords: Pantanal; Conservation unit; Biophysical parameters.

Análise de parâmetros biofísicos na detecção de mudanças de cobertura e uso do solo em uma unidade de conservação no Pantanal brasileiro

Com o objetivo de preservar a Reserva Particular do Patrimônio Natural do SESC Pantanal (RPPN) foi criada em 1997. As fisionomias ali apresentam transições rápidas, o que dificulta a classificação do uso do solo e dinâmica complexa do regime de inundações. Portanto, o objetivo deste trabalho foi avaliar a dinâmica da temperatura e os parâmetros biofísicos em uma reserva no Pantanal brasileiro. Dados de precipitação e imagens do satélite Landsat 5 foram usados ??para calcular os parâmetros biofísicos. Nossos resultados demonstram que a maior área é ocupada por vegetação arbustiva, seguida por campos de pastagem, cambarazal e murundus. O albedo, a temperatura superficial e o NDVI apresentaram diferenças significativas ao longo do período estudado e nas estações seca e chuvosa. Os índices de vegetação apresentaram os maiores valores nos anos de 1989 durante o período chuvoso, enquanto os maiores valores de albedo e temperatura superficial foram obtidos uma década depois, períodos que precedem a formação e expansão da RPPN SESC-Pantanal. O LAI não apresentou diferença significativa entre todo o período estudado e entre as estações seca e chuvosa, o que demonstra que grande parte da vegetação se manteve durante o período de formação, expansão e preservação da RPPN.

Palavras-chave: Pantanal; Unidade de conservação; Parâmetros biofísicos.

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Victor Hugo de Morais Danelichen
Universidade de Cuiabá, Brasil
http://lattes.cnpq.br/3461595808977435
http://orcid.org/0000-0003-4791-3301
danelichen@fisica.ufmt.br

Marcelo Sacardi Biudes
Universidade Federal de Mato Grosso, Brasil
http://lattes.cnpq.br/7273935697798004
http://orcid.org/0000-0002-0795-8946
marcelo@fisica.ufmt.br

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INTRODUCTION

The main Brazilian biomes are the Amazon, the Caatinga, the Atlantic Forest, the Cerrado, the Pantanal, and the Pampa, or Campos do Sul. The Amazon holds the largest protected area with 25.5% of its total area in conservation units, the Atlantic Forest, the Cerrado, and the Caatinga, hold 9%, 8% and 7% (MARTINS FILHO et al., 2019). The Pampas territories or Campos Sulinos and Pantanal biomes have the fewest protected areas, which corresponds to about 3% of the total area of each. With regard to the Cerrado biome, and part of the Pantanal is an extension of it, it has for some time been seen as an area occupied by agricultural activity, and its intensification has become the greatest threat to the existence of this biome (SOARES et al., 2020).

In order to preserve a portion of the Pantanal biome, the SESC Pantanal Private Natural Heritage Reserve (RPPN) was established in 1997 (DANELICHEN et al., 2019), under the responsibility of the Social Service of Commerce (SESC), located in the municipality of Barão de Melgaço, northeast of the Pantanal of Mato Grosso. The RPPN covers an area of 1,076 km^2. In 2002, the RPPN was recognized as a *Ramsar site* and considered a Priority Area for Biodiversity Conservation (BRANDÃO et al., 2011).

In general, four large physiognomic groups are identified where the reserve is inserted: savannahs and dry forests, these over more drained land (center and east of the Reserve), wetlands and non-forested floodplain, lower portions of the Reserve under marked influence of the flooding of the Cuiabá River (CORDEIRO, 2004). A striking physiognomy in the landscape of the Reserve is Cambarazal, a forest monodominate formation in a floodable area dominated by *Vochysia divergens* Pohl, presenting its greatest concentration in the Pantanal. As in all of the Pantanal, the physiognomies found in the RPPN are many, presenting fast and strong transitions, which makes it difficult to accurately classify land cover and use (DANELICHEN et al., 2019). Another great difficulty is due to the fact that many terminologies have been used over the years, based on the proposal and the thematic map by Cordeiro et al. (2002) and Hasenack et al. (2003). In view of this, there is a need to establish new classifications regarding the use and coverage of the RPPN soil, which allows for a detailed study of the dynamics of vegetation and the local microclimate (HASENACK et al., 2003; HOFMANN et al., 2010; DANELICHEN et al., 2019).

In order to contemplate variations in the time-space plan, studies on land use are of great importance in monitoring the biome involved (LEITE et al., 2012). The monitoring of the dynamics of the biophysical parameters of the earth's surface allows the diagnosis of natural and anthropic changes in the landscape of an ecosystem (CUNHA et al., 2012). The computation of these parameters, such as albedo, surface temperature and vegetation indices, on a regional scale, would represent a large expenditure of material and human resources, since the construction of maps for each parameter are indicators of the health of that biome (OLIVEIRA et al., 2012). In this way, remote sensing is a viable option for mapping the amount of leaves and vegetation biomass (ROCCHINI, 2013; JIANG et al., 2013). In this context, it is practically impossible to gather exhaustive information about the geometry of the environment and species variations in the same space and time in an ecosystem (PALMER, 2007).

Different methodologies for identifying and evaluating changes in structure, physiognomy and dynamics of vegetation are employed, among them, the detection of change by vegetation indices stands out (CALERA et al., 2004). The best-known indices are: Normalized Difference Vegetation Index - NDVI (ROUSE et al., 1973) and Soil Adjusted Vegetation Index - SAVI (HUETE, 1988). NDVI is the most used index in studies related to vegetation cover, since it allows the assessment of vegetation conditions and their respective spatial-temporal dynamics (HUETE et al., 1999). It is more sensitive to the presence of pigments that act in photosynthetic processes, specific to the content of chlorophyll (HUETE et al., 1997; 2002). The SAVI index, proposed by Huete (1988), reduces the effect of the soil on different densities of vegetation cover, since it considers the influence of the soil on vegetation. However, a peculiarity inherent to these indices is the asymptotic saturation, which makes it less sensitive to the detection of variations in green biomass under conditions of high leaf area indices (HUETE, 2002). Therefore, evaluating the leaf area index - LAI is of paramount importance in studies of interest in the knowledge of phenomena at different scales, such as leaf to canopy, providing important information for the parameterization of physiological based models, and also the knowledge of this. parameter is necessary for the validation of production data and vegetation cover, which can also be obtained by remote sensing techniques (WATSON, 1952; LUNZ, 2006; BARBOSA et al., 2012; SOUZA et al., 2018).

Throughout history it has been used more widely in the mapping of leaf area and forest biomass. Hall et al. (1995) presented a review of algorithms used to extract structural parameters from the canopy using images from orbital sensors, and great progress has been made since then. In recent years, Zheng et al. (2009) provided an overview of how LAI can be measured in the field, by air, and also by space. Bergen et al. (2009) reviewed vegetation structure measurements based on data from LIDAR - Light Detection and Ranging and RADAR. Jiang et al. (2013) provide an example of how to estimate the probability of spatial distribution of bryophyte plants, based on weighted regression models, using the NDVI. Thus, data from orbital sensors can: (i) provide reference data to outline patterns of vegetation communities, (ii) examine the community structure (above-ground biomass estimate), and (iii) predict patterns of the balance of energy and CO2 flow at a variety of spatial scales (ATKINSON et al., 2013). Therefore, the object of work was to evaluate the space-time dynamics of temperature, albedo and vegetation indices in a reserve in the Brazilian Pantanal using data from orbital sensors.

MATERIALS AND METHODS

Study Area

The study was carried out in the Private Reserve of Natural Heritage - RPPN SESC Pantanal in the municipality of Barão de Melgaço - MT, Brazil, with coordinates of 16º39'50''S and 56º47'50''O and altitude of 120 m (Figure 1). The region is under Aw climatic domain, according to the Köppen classification, the average annual temperature ranges from 24.9 to 25.4ºC, with precipitation between 1300 to 1400 mm per year, with the dry season between April and September and the rainy season. Between October and March

(HASENACK et al., 2003). The soil was classified as GLEISSOLO HÁPLICO Ta Distrófico (EMBRAPA, 2006).

Earthly data

Precipitation data provided by Marechal Rondon International Airport in Várzea Grande - MT, approximately 106 km from the RPPN, were used. The choice of these data was due to the absence of failures during 25 years, from 1984 to 2009 (Figure 2).

Orbital sensor data

Twelve images of the Landsat 5 thematic mapper, orbit 226 and points 71/72 were acquired from the National Institute of Space Research (INPE), two images referring to: September 2, 1984, December 21, 1989, August 11, 1999, November 15, 1999, September 4, 2008 and November 10, 2009. Two images of each date were chosen, due to much of the RPPN being at point 72 and the smallest in 71. The choice of these images is due to the fact that they present complete absence of clouds, which implies the accuracy of the results obtained, and throughout the period imaged by the satellite (1984 to 2009) are the only images that intersect on the same date, which allowed the realization of the junction of the points (71 and 72). Another reason for the selection of images is to analyze the period before the years 1990 (images 1984 and 1989), when the RPPN was not a nature reserve, the period of 1999, when then the RPPN is already expanded, and the subsequent conditions of the RPPN, years 2008 and 2009 (HOFMANN, 2010).

These images were stacked band by band and then georeferenced based on an orthorectified reference image obtained on the landsat[1] page. A classification of the soil cover conditions of the RPPN was performed with images from 2008, the year that showed less influence of aerosols and lower rainfall index, based on the proposal of Cordeiro (2004). Ten categories were characterized, expressing the conditions of vegetation and soil: Murundus field, Cambarazal, Dense forest, Shrub, Exposed soil, River, Lagoon, Cuiabá river, Pasture and Open forest (Table 1, Figure 1).

Steps for estimating Surface Temperature, Albedo, and Vegetation Indices

Radiometric Calibration

The spectral radiance of each band ($L_{\lambda i}$) consists of converting the Digital Number (ND) of each pixel of the image into monochrome spectral radiance. The monochrome radiance of each of the seven bands is obtained according to the expression (MARKHAM et al., 1987):

$$L_{\lambda i} = a_i + \left(\frac{b_i - a_i}{255}\right) \times ND \qquad (1)$$

where: $L_{\lambda i}$ is the spectral radiance of each band (W.m^{-2} st^{-1} µm^{-1}); a_i and b_i are calibration coefficients of each band (W.m^{-2} st^{-1} µm^{-1}) and i are the bands (1, 2, ..., 7) of Landsat 5.

[1] htpp://www.landsat.org

Reflectance

The monochrome reflectance *($\rho_{\lambda i}$)* is defined as a relationship between the reflected radiation flow and the incident radiation flow:

$$\rho_{\lambda i} = \frac{\pi \, . \, L_{\lambda i}}{K_{\lambda i} \, . \, Cos\, Z \, . \, d_r} \tag{2}$$

where $k_{\lambda i}$ is the spectral solar irradiance of each band at the top of the atmosphere (Wm^{-2} µm^{-1}), *Z* is the solar zenithal angle and d_r is the square of the ratio between the average Distance Earth-Sun (IQBAL, 1983).

Surface albedo

Considering that the Earth's atmosphere produces interference in solar radiation and reflected radiation, the calculated albedo at the top of the atmosphere lacks corrections due to absorption and scattering processes. These corrections can be obtained by the equation below:

$$\alpha_{sup} = \frac{\alpha_{toa} - \alpha_{atm}}{\tau_{sw}^2} \tag{3}$$

where αsup is the albedo of the surface, α_{toa} is the planetary albedo, α_{atm} is the reflectance of the atmosphere itself, which varies between 0.025 and 0.040, however it has been recommended the value of 0.03 based on Bastiaanssen (2000) and τ_{sw} is the atmospheric transmissivity that can be obtained by Allen et al. (2007):

$$\tau_{sw} = 0{,}35 + 0{,}627exp\left[\frac{-0{,}00146P}{K_t cos\theta_{hor}} - 0{,}075\left(\frac{W}{cos\theta_{hor}}\right)^{0{,}4}\right] \tag{4}$$

where θ_{hor} is the solar zenital angle, obtained; *P* is the average atmospheric pressure in kPa; k_t is the turbidity coefficient of the atmosphere, being k_t = 1 for clear sky and k_t = 0.5 for extreme turbidity (ALLEN, 1996); *W* is the water precipitable in mm, calculated according to the equation proposed by Garrison et al. (1990):

$$W = 0{,}14e_a P_{ar} + 2{,}1 \tag{5}$$

Atmospheric pressure can be obtained according to (ASCE-EWRI, 2005):

$$P = 101{,}3\left(\frac{T_a - 0{,}0065z}{T_a}\right)^{5{,}26} \tag{6}$$

where T_a is the air temperature, in Kelvin and *z* is the altitude.

Vegetation indices

The Normalized Difference Vegetation Index (NDVI) was obtained through the ratio between the difference of the reflectivity of the IV-close ($\rho_{\lambda 4}$) and the red ($\rho_{\lambda 3}$), by the sum of them (ALLEN et al., 2007):

$$NDVI = \frac{\rho_{\lambda 4} - \rho_{\lambda 3}}{\rho_{\lambda 3} + \rho_{\lambda 4}} \tag{7}$$

where $\rho_{\lambda 4}$ and $\rho_{\lambda 3}$ correspond, respectively, to Landsat 5 – TM bands 4 and 3.

The Soil Adjusted Vegetation Index (SAVI) is a variation of NDVI, causing soil effects to be mitigated. For its calculation, the Huete model (1988) was used:

$$SAVI = \frac{(1 + L)(\rho_{\lambda 4} - \rho_{\lambda 3})}{(L + \rho_{\lambda 4} + \rho_{\lambda 3})} \tag{8}$$

Factor *L* (= 0.5) is a function of vegetation density and its determination requires an a priori knowledge of the amount of vegetation.

The Leaf Area Index (LAI)is defined by the ratio between the leaf area of all vegetation per unit of area used by this vegetation. The LAI was computed by the following empirical equation obtained by Allen et al. (2002):

$$LAI = -\frac{ln\left(\frac{0,69 - SAVI}{0,59}\right)}{0,91} \quad (9)$$

Surface temperature

Surface temperature (T_s) was obtained based on the spectral radiance of the thermal band ($L_{\lambda 6}$) and emissivity (ε_{NB}), according to the methodology of Allen et al. (2002). The expression below is used for obtaining it in Kelvin (K):

$$T_s = \frac{k_2}{\left(\frac{\varepsilon_{NB} k_1}{L_{\lambda 6}} + 1\right)} \quad (10)$$

where k_1 and k_2 are calibration constants of the Landsat thermal band 5, and are worth k_1 = 607.76 Wm-2 sr-1 µm-1 and k_2 = 1260.56 k. For Landsat 7, k_1 = 666.09 Wm^{-2} sr^{-1} μm^{-1} and k_2 = 1282.71 k.

Statistical analysis

The Kruskal-Wallis test was used to verify whether the variables had a significant difference between the years of obtaining the images by Landsat 5 satellite and the Mann Whitney test (WILKS, 2011), if the data collection period (rainy season, from October to April; and dry season, from May to September) caused statistical difference *(p-value* < 0.05) in albedo, surface temperature, and NDVI, SAVI and LAI vegetation indices.

RESULTS AND DISCUSSION

In view of the influence of precipitation on vegetation, the period of its lowest occurrence was chosen to affect the classification of soil cover in the RPPN (Figure 1). In the analysis of the scene in 2008, the largest area is that of shrub vegetation, about 36.65%, followed by pasture, cambarazal and murundus field areas, 18.87, 17.03 and 13.79%, respectively (Table 1). The shrub vegetation that corresponds to most of the reserve, has its diffuse and fragmented distribution in the landscape in non-floodable areas of higher land (CORDEIRO, 2004).

The cambarazal and dense forest on the banks of the Cuiabá River present equally dense soil cover, which results in a similar behavior. The occurrence of Cambará, *Vochysia divergens* Pohl, is mainly related to seasonally flooded areas (PRANCE et al., 1982; SILVA et al., 2000; HOFMAN et al., 2010). When compared to other formations, cambarazal is imposed by the average canopy height (HOFMAN et al., 2010), being the highest recorded within the RPPN (Figure 1). The murundus fields are formed by a typical landscape of the Cerrado biome in central Brazil, are characterized by gramineous fields where there is a large distribution of rounded elevations (murundus) coated with woody Cerrado vegetation (OLIVEIRA FILHO, 1992; HOFMAN et al., 2010). Before the implementation of the RPPN (before 1997) much of it was widely used as natural pasture for agricultural activity during the dry periods, due to the remained of water content in the soil even during the dry season (CORDEIRO, 2004).

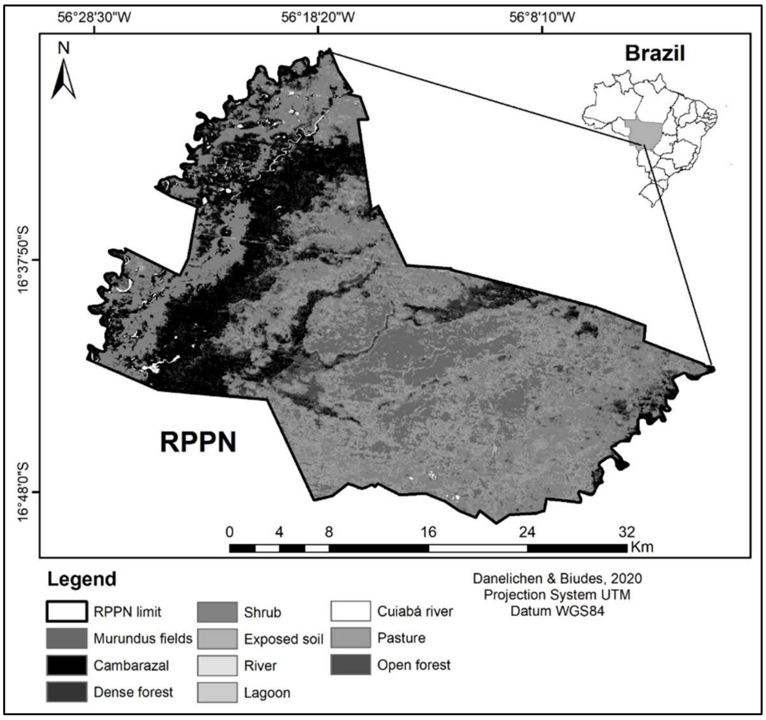

Figure 1: Classification of soil cover conditions of RPPN in 2008.

Table 1: RPPN classes.

Classification	Area (km²)	%
Murundus fields	12116.315	13.797
Cambarazal	14960.579	17.036
Dense forest	7012.173	7.985
Shrub	32187.012	36.653
Exposed soil	220.514	0.251
River	375.810	0.427
Lagoon	4.325	0.004
Cuiabá river	413.834	0.471
Pasture	16574.816	18.874
Open forest	3948.570	4.496

Precipitation ranged from 1005.3 to 1707.8 mm, with a mean rainfall of 1357.7 mm, over the entire period studied, 25 years. Among the period analyzed that corresponds to the dates of the images, years 1984, 1989, 1999, 2008 and 2009, the highest accumulation occurred in 1999 and lower in 2008, with a mean rainfall of 1381.67 mm (Figure 2). The accumulation recorded in 1999 is possibly due to the El Niño phenomenon, which has a frequency of approximately seven years, culminating in 2008. The probable cause of interference in the rains on this phenomenon, which is little or almost nothing known, if it causes changes in the precipitation regime of the Midwest region of the country, since its "remarkable" consequences are to the north and south of Brazil (MELO, 2000). The accumulation in 2008 is related to the atmospheric conditions of October 2008 influenced by the end of the La Niña event (INPE, 2009).

Albedo was significantly affected by the years of images and seasons (*p-value* < 0.05). Only between the pairs of years 1984 and 1999, 1999 and 2008, 1999 and 2009, 2008 and 2009 did albedo not present significant difference (Table 2 and 3). Albedo estimates show higher values in 1984 and 1999 (Table 4). In the rainy season of 1999, albedo reaches 60% in the center of the RPPN, with a higher average of 31% and a higher standard error of 0.163, caused by the low vegetation cover, possibly due to the water content in the soil and water lamina formed during this season in the Pantanal (CORDEIRO, 2004; BIUDES, 2009; HOFFMAN et al., 2010).

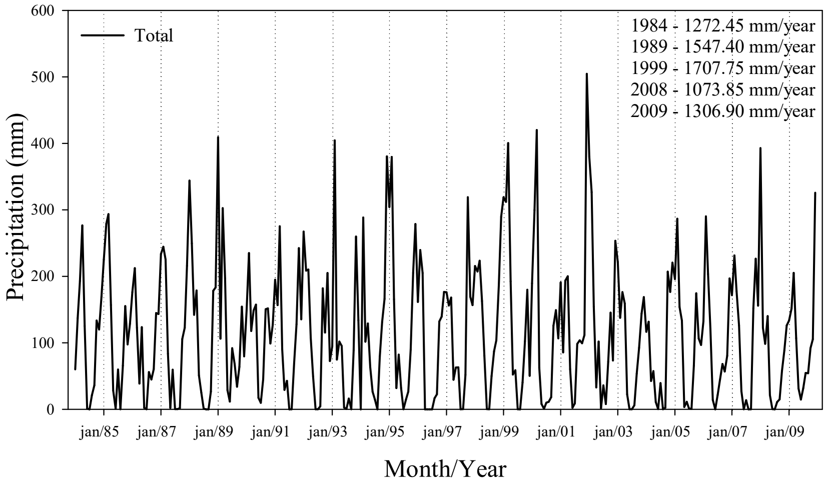

Figure 2: Distribution of precipitation measured monthly at Marechal Rondon International Airport, Cuiabá – MT, Brazil, from 1984 to 2009.

The lowest and lowest averages are also found in the rainy season in 1989, 1999 and 2009. The lowest standard deviation 0.104 was observed in the dry season in 1984 (Table 4). Low albedo values were found near the Cuiabá River, lagoon and flooded areas, water bodies usually present albedo 0.025 to 0.034 (ALLEN et al., 2002). The higher values of albedo are associated with changes in land use and occupation, which may have contributed to affect the climate locally, and in 1984 the RPPN suffered an impact of agricultural activity, and in 1997 the process of converting pasture into forest began with the preservation of the reserve (CORDEIRO, 2004; HOFMANN, 2010; BRANDÃO et al., 2011).

Table 2: Kruskal-Wallis test performed with data referring to the variables: albedo, surface temperature, NDVI, SAVI and LAI. The overwritten indexes (a, b, c and d) indicate whether or not there was a significant difference between the period of obtaining the images.

Variable	09/02/1984	12/21/1989	08/11/1999	11/15/1999	09/04/2008	11/10/2009
Albedo	a	b	c	a	c	c
Temperature	a	b	b	c	d	b
NDVI	a	bc	ab	ab	a	c
SAVI	a	b	abc	abc	ac	abc
LAI	a	a	a	a	b	a

Table 3: Mann Whitney test performed with data referring to the variables: albedo, surface temperature, NDVI, SAVI and LAI. The overwritten indices (a, b, c and d) indicate whether or not there was a significant difference between the dry and rainy seasons.

Variable	Dry	Rainy
Albedo	a	b
Temperature	a	b
NDVI	a	b
SAVI	a	a
LAI	a	a

Table 4: Maximum, minimum, average and standard deviation values of the estimates of the estimates of surface temperature, albedo, NDVI, SAVI and LAI of the entire analyzed period.

Variable	Dates	Maximum	Minimum	Average	Standard deviation
Temperature (ºC)	09/02/1984	40.84	20.84	30.90	5.73
	12/21/1989	33.84	0.84	17.11	9.66
	08/11/1999	49.84	-0.16	24.90	14.53
	11/15/1999	50.84	22.84	36.69	8.04
	09/04/2008	36.84	18.84	27.76	5.16
	11/10/2009	25.84	0.84	12.90	7.31
Albedo	09/02/1984	0.518	0.159	0.339	0.104
	12/21/1989	0.379	0.002	0.191	0.109
	08/11/1999	0.489	0.041	0.265	0.130
	11/15/1999	0.599	0.037	0.318	0.163
	09/04/2008	0.513	0.066	0.290	0.130
	11/10/2009	0.538	0.001	0.270	0.156
NDVI	09/02/1984	0.734	0.004	0.369	0.212
	12/21/1989	0.991	0.001	0.496	0.288
	08/11/1999	0.781	0.001	0.391	0.227
	11/15/1999	0.824	0.004	0.414	0.239
	09/04/2008	0.750	0.004	0.377	0.217
	11/10/2009	0.977	0.003	0.490	0.283
SAVI	09/02/1984	0.708	0.003	0.356	0.204
	12/21/1989	0.879	0.002	0.441	0.255
	08/11/1999	0.763	0.002	0.382	0.221
	11/15/1999	0.775	0.002	0.389	0.224
	09/04/2008	0.675	0.001	0.338	0.196
	11/10/2009	0.724	0.002	0.363	0.210
LAI	09/02/1984	5.980	0.004	2.990	1.731
	12/21/1989	5.980	0.004	2.990	1.731
	08/11/1999	5.980	0.005	2.990	1.731
	11/15/1999	5.980	0.005	2.990	1.731
	09/04/2008	4.460	0.005	2.231	1.291
	11/10/2009	5.980	0.004	2.990	1.731

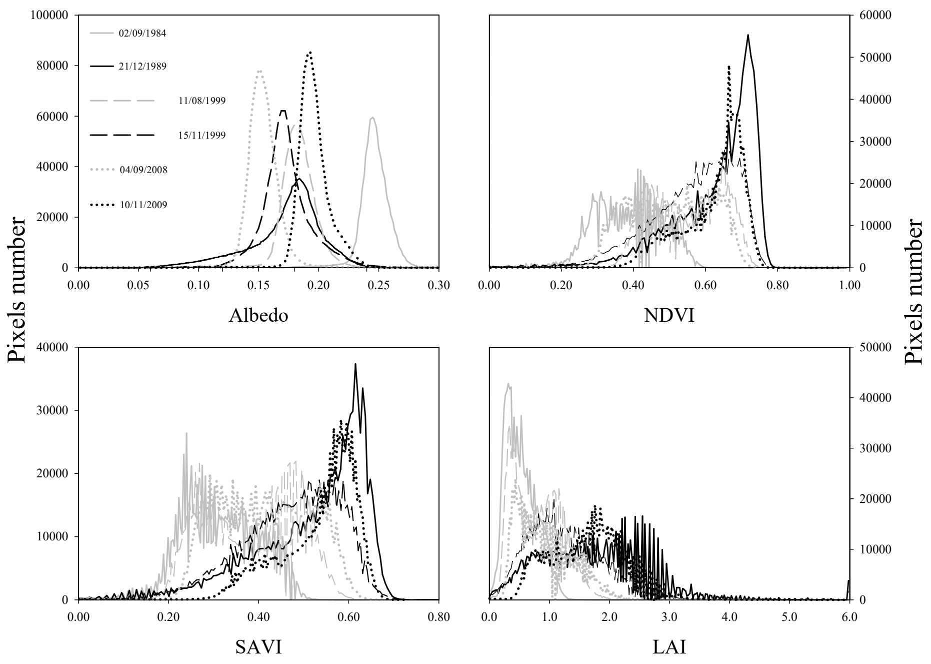

Figure 3: Histograms of the albedo, NDVI, SAVI and LAI charts of the entire analyzed period.

Surface temperature was significantly affected by the years of imaging and seasons *(p-value* < 0.05). Only between the pairs of years 1989 and 1999, 1989 and 2009, 1999 and 2009 there was no difference in the albedo (Table 2 and 3). The exposed pasture and soil areas presented the highest temperatures, while the regions near the Cuiabá River, areas of dense forest and cambarazal, presented the lowest temperatures over the years (Figure 4). The highest surface temperature values were found in 1999, in the rainy season, while the lowest values were found in 2009. The largest standard error is observed during the dry season in 1999, although the smallest standard error occurred in 1984 (Table 4). Andrade et al. (2012) studying the Pantanal biome found higher surface temperature values in areas of agriculture and livestock activities (35.85 to 36.85ºC), while the lowest values were found in the wettest and floodable surface areas (+-24.85ºC), these results corroborate the values estimated in this study.

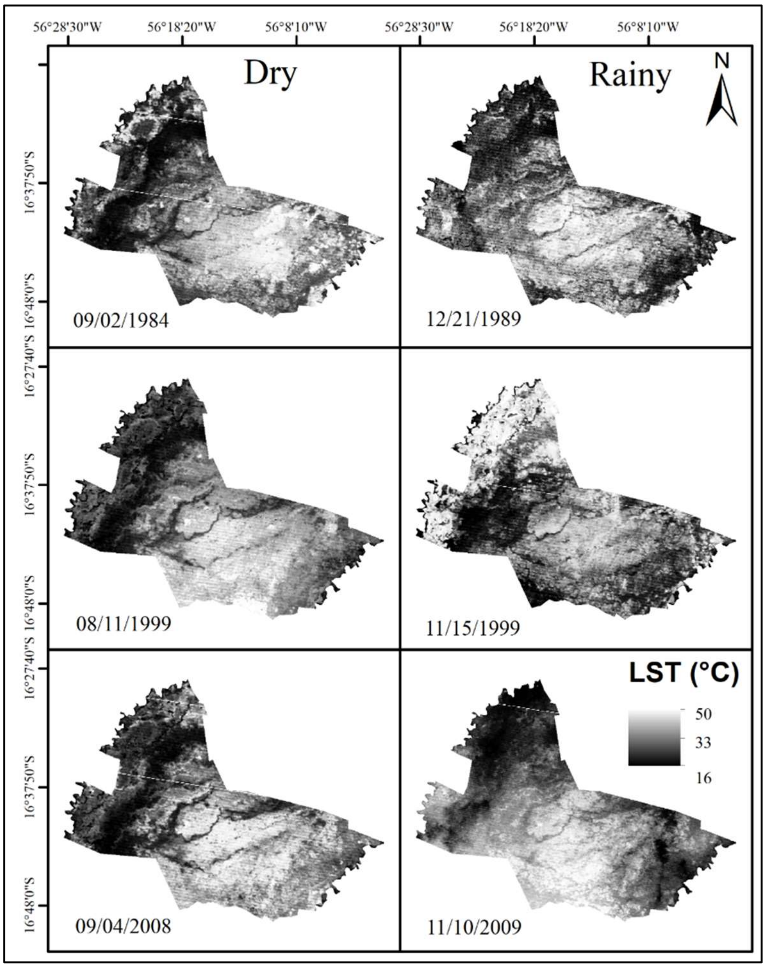

Figure 4: Surface Temperature Maps (LST) for the RPPN region in the dry and rainy seasons from 1984 to 2009.

The NDVI was significantly affected by the years of obtaining the images and by the stations *(p-value* < 0.05). However, for the years 1984, 1999 and 2008, there was no significant difference between the estimated NDVI (Table 2 and 3). The highest NDVI values were obtained in 1989 and 2009, both in the rainy season, while the lowest values were observed in 1984 during the dry season. The largest standard error was obtained in 1989 and lower in 1984 (Table 4). It is observed throughout the studied period that NDVI has a spectral characteristic for each season, in drought with values distributed between 0.20 and 0.65, and in the rainy season with values between 0.25 to 0.80 m^2m^{-2} (Figure 3). The NDVI variability is closely linked to seasonality and rainfall, Becerra et al. (2009) studying the dynamics of vegetation indices, such as NDVI and EVI, and its relationship with precipitation on the Cerrado biome observed that the highest values of NDVI and EVI were found in the period with the highest precipitation.

The SAVI was significantly affected by the years of obtaining the images, but in the stations, there was no significant difference (*p-value* < 0.05). The years that did not differ were 1999 and 2009, 1999 and 2008, 2008 and 2009 (Table 2 and 3). The highest SAVI values and the highest standard error were obtained in 1989, while the lowest values and lowest standard error were found in 2008 (Table 4). During the dry season, their values were distributed in the histogram with values that concentrate between 0.20 and 0.60, while in the rainy season 0.45 and 0.65 m^2m^{-2} (Figure 3). This variation is associated with its empirical formulation as a function of NDVI (difference ratio of Near IV and V) and a correction factor for soil effects (*L*), the latter being parameterized for growing regions (HUETE, 1988). Although SAVI is an index of vegetation sensitive to surface variation, for the Pantanal Biome region these variations are small. A study conducted by Valeriano et al. (2007) using the digital model SRTM data found that the Pantanal presents a low slope relief, devoid of topographic features and marked by features associated with plant Canoeuls.

The LAI was the only parameter that did not present significant difference between years and between seasons, although 2008 presented different from the other years (Table 2 and 3). It is observed that the LAI throughout the studied period did not present variations around its means, except for 2008, a year with less rainfall accumulation, there is also a spectral signature in the dry and rainy season, where the LAI values in the rainy season distribute spatially permeating a limit of 3 m^2m^{-2}, while in the dry season these values concentrate in 2 m^2m^{-2}, demonstrated by histograms between years, respectively (Figure 3). The absence of LAI variability over the years and SAVI in the stations in the RPPN, possibly associated with the mathematical formulations of these indices (HUETE, 1988; ALLEN, 2002), considering that they were calibrated and parameterized for crop regions. The crops, with which the authors worked, are agricultural crops, desert areas, whose heterogeneity may be debatable, especially when compared to a forest condition, in which heterogeneity is undoubtedly much greater.

CONCLUSIONS

Ours results show that the largest area of RPPN is occupied by shrubby vegetation, about 36.65%, followed by pasture, cambarazal and murundus field areas, 18.87, 17.03 and 13.79%, respectively. Precipitation ranged from 1005.3 to 1707.8 mm, with a mean rainfall of 1357.7 mm, over the entire period studied, 25 years.

Albedo, surface temperature, and NDVI showed significant difference over the studied period and in the dry and rainy seasons. However, LAI and SAVI were similar between years and between seasons. The NDVI and SAVI indices showed the highest values in 1989 during the rainy season, while the highest values of albedo and surface temperature were obtained one decade later, 1999, periods preceding the formation and expansion of the RPPN SESC - Pantanal.

The LAI was the only physical parameter that did not present significant difference between the entire period studied and between the dry and rainy seasons, which demonstrates that most of the vegetation; shrubby vegetation, pasture and cambarazal maintained during the period of formation, expansion and preservation of RPPN SESC - Pantanal. It is suggested for future work carried out in the Pantanal biome using data from orbital sensors to estimate vegetation indices, perform parameterization of the empirical equations of the LAI and obtain accurate correction factor *L* for SAVI with local measured data.

REFERENCES

ALLEN, R. G.. Assessing integrity of weather data for use in reference evapotranspiration estimation. **Journal of Irrigation and Drainage Engineering,** v.122. n.2, p.97-106, 1996.

ALLEN, R.; BASTIAANSSEN, W.; WARTES, R.; TASUMI, M.; TREZZA, R.. **Surface energy balance algorithms for land (SEBAL), Idaho implementation:** Advanced training and user's manual, version 1.0. 2002.

ALLEN, R.; TASUMI, M.; TREZZA, R.. Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC) – Model. **Journal of Irrigation and Drainage Engineering,** v.133, n.395, p.380-394, 2007.

ANDRADE, R. G.; SEDIYAMA, G. C.; PAZ, A. R.; LIMA, E. P.; FACCO, A. G.. Geotecnologias aplicadas à avaliação de parâmetros biofísicos do Pantanal. **Pesq. Agropec. Bras.,** Brasília, v.47, n.9, p.1227-1234, 2012.

ASCE-EWRI. The ASCE standardized reference evapotranspiration equation. In: Allen, R. G.; Walter, I. A.; Elliot, R. L.. **Environmental and Water Resources Institute (EWRI) of the American Society of Civil**. Reston: ASCE, 2005.

ATKINSON, D. M.; TREITZ, P. 2013. Modeling Biophysical Variables across an Arctic Latitudinal Gradient Using High Spatial Resolution Remote Sensing Data. **Arctic, Antarctic, and Alpine Research,** v.45, n.2, p.161-178.

BARBOSA, J. P. R. A. D.; MARTINS, G. A.; FERREIRA, R. T.; PENNACCHI, J. P.; SOUZA, V. F.; SOARES, A. M.. Estimativa do IAF de cafeeiro a partir do volume de folhas e arquitetura da planta. **Coffee Science,** v.7, n.3, p.267-274, 2012.

BASTIAANSSEN, W. G. M.. SEBAL - Based sensible and latent heat fluxes in the irrigated Gediz Basin, Turkey. **Journal of Hydrology,** v.229, p.87-100, 2000.

BECERRA, J. A. B.; SHIMABUKURO, Y. E.; ALVALÁ, R. C. S.. Relação do padrão sazonal da vegetação com a precipitação na região de Cerrado da Amazônia Legal, usando índices espectrais de vegetação. **Revista Brasileira de Meteorologia,** v.24, p.125-134, 2009.

BERGEN, K. M. S.; GOETZ, S. J.; DUBAYAH, R. O.; HENEBRY, G. M.; HUNSAKER, C. T.; IMHOFF, M. L.; NELSON, R. F.; PARKER, G. G.; RADELOFF, V. C.. Remote sensing of vegetation 3-D structure for biodiversity and habitat: Review and implications for lidar and radar spaceborne missions. **Journal of Geophysical Research: Biogeosciences,** v.114, G00E06, 2009.

BIUDES, M. S.; CAMPELO JÚNIOR, J. H.; NOGUEIRA, J. S.; SANCHES, L.. Estimativa do balanço de energia em cambarazal e pastagem no norte do Pantanal pelo método da razão de Bowen. **Revista Brasileira de Meteorologia**, v.24, n.2, p.135-143, 2009.

BRANDÃO, L. G.; ANTAS, P. T. Z.; OLIVEIRA, L. F. B.; PÁDUA, M. T. J.; PEREIRA, N. C.; VALUTYK, W. W.. **Plano de manejo da Reserva Particular de Patrimônio Natural SESC Pantanal.** SESC, 2011.

CALERA, A.; GONZÁLEZ-PIQUERAS, J.; MELIA, J.. Monitoring barley and corn growth from remote sensing data at field scale. **Int. J. Remote Sens.**, v.25, p.97-109, 2004.

CORDEIRO, J. L. P.; HASENACK, H.; OLIVEIRA, L. F. B.. **Estrutura e heterogeneidade da paisagem da estância ecológica do SESC Pantanal:** evolução da paisagem na RPPN SESC/ Pantanal*.* Porto Alegre: Universidade Federal do Rio Grande do Sul, 2002.

CORDEIRO, J. L. P.. **Estrutura e heterogeneidade da paisagem de uma unidade de conservação no nordeste do Pantanal (RPPN SESC Pantanal), Mato Grosso, Brasil:** efeitos sobre a distribuição e densidade de antas *(Tapirus terrestris)* e de cervos-do-pantanal *(Blastocerus dichotomus).* Tese (Doutorado em Ecologia) - Universidade Federal do Rio Grande do Sul, Porto Alegre, 2004.

CUNHA, J. E. B. L.; RUFINO, I. A. A.; SILVA, B. B.; CHAVES, I. B.. Dinâmica da cobertura vegetal para a Bacia de São João do Rio do Peixe, PB, utilizando-se sensoriamento remoto. **Revista Brasileira de Engenharia Agrícola e Ambiental***,* v.16, p.539-548, 2012.

DANELICHEN, V. H. M.; PEREIRA, O. A.; NOVAIS, J. W. Z.; BIUDES, M. S.; NOGUEIRA, J. S.; CORREIA, A. R.. Assessment of Land Use in A Conservation Unit in the Brazilian Pantanal by Remote Sensing. **Australian Journal of basic and Applied Sciences**, v.13, p.141-150, 2019.

EMBRAPA. **Sistema Brasileiro de Classificação de Solos.** Brasília: Embrapa-SPI; Rio de Janeiro: Embrapa-Solos, 2006.

GARRISON, J. D.; ADLER, G. P.. Estimation of precipitable water over the United State for aplication to the division of solar radiation into its direct and difuse coponents. **Solar Energy,** v.44, n.4, p.225-241, 1990.

HALL, D. K.; RIGGS, G. A.; SALOMONSON, V. V.. Development of methods for mapping global snow cover using moderate resolution imaging spectroradiometer data. **Remote Sensing of Environment**, v.54, p.127-140, 1995.

HASENACK, H.; CORDEIRO, J. L. P.; HOFMANN, G. S.. **O clima da RPPN SESC Pantanal.** Porto Alegre: UFRGS, 2003.

HOFMANN, G. S.; HASENACK, H.; OLIVEIRA, L. F. B.; CORDEIRO, J. L. P.. **O clima na Reserva Particular do Patrimônio Natural SESC Pantanal.** Serviço Social do Comércio, 2010.

HUETE, A.; DIDAN, K.; MIURA, T.; RODRIGUEZ, E. P.; GAO, X.; FERREIRA, L. G.. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. **Remote Sensing of Environment**, v.83, p.195-213, 2002.

HUETE, A.; JUSTICE, C.; VAN LEEUWEN, W.. **MODIS vegetation index (MOD 13):** algorithm theoretical basis document. Version 3. Washington: National Aeronautics and Space Administration, 1999.

HUETE, A. R.. A soil-adjusted vegetation index (SAVI). **Remote Sensing of Environment,** v.25, p.295-309, 1988.

HUETE, A. R.; DIDAN, K.; SHIMABUKURO, Y. E.; RATANA, P.; SALESKA, S. R.; HUTYRA, L. R.; YANG, W.; NEMANI, R. R.; MYNENI, R.. Amazon rainforests green-up with sunlight in dry season. **Geophysical Research Letters**, v.33, p.1-4, 2006. **DOI:** http://doi.org/10.1029/2005GL025583

HUETE, A. R.; LIU, H. Q.; BATCHILY, K.; VAN LEEUWEN, W.. A comparison of vegetation indices over a global set of TM images for EOS-MODIS. **Remote Sensing of Environment,** v.59, p.440-451, 1997.

INPE. Instituto Nacional de Pesquisas Espaciais. **Boletins climáticos.** INPE, 2009.

IQBAL, M.. **An Introduction to Solar Radiation**. New York: Academic Press, 1983.

JIANG, Y.; BIE, C. A. J. M.; WANG, T.; SKIDMORE, A. K.; LIU, X.; SONG, S.; SHAO, X.. Hyper-temporal remote sensing helps in relating epiphyllous liverworts and evergreen forests. **Journal of Vegetation Science,** v.24, p.214-226, 2013.

LEITE, M. R.; BRITO, J. L. S.. Avaliação de desempenho entre modelos de obtenção de temperatura de superfície por sensores remotos. **OBSERVATORIUM: Revista Eletrônica de Geografia,** v.4, n.12, p.73-89, 2012.

LUNZ, A. M. P.. **Crescimento e produtividade do cafeeiro sombreado e a pleno sol**. Tese (Doutorado em Fitotecnia) - Escola Superior de Agricultura “Luiz de Queiroz”, São Paulo, 2006.

MARKHAM, B. L.; BARKER, J. L.. Thematic mapper band pass solar exoatmospherical irradiances. **International Journal of Remote Sensing,** v.8, n.3, p.517-523, 1987.

MARTINS FILHO, I. A.; NEVES, A. J.; SILVA, G. E.; VIEIRA, A. S.. Áreas de proteção ambiental e a preservação do bioma cerrado. **REBESP**, v.12, p.10-19, 2019.

MELO, M. L.. Impacto do fenômeno El Niño sobre a região centro-oeste do Brasil. In: CONGRESSO BRASILEIRO DE METEOROLOGIA. **Anais**. 2000.

OLIVEIRA, L. M. M.; MONTENEGRO, S. M. G. L.; ANTONIO, C. D. A.; SILVA, B. B.; MACHADO, C. C. C.; GALVÍNCIO, J. D.. Análise quantitativa de parâmetros biofísicos de bacia hidrográfica obtidos por sensoriamento remoto. **Pesq. Agropec. Bras.,** Brasília, v.47, n.9, p.1209-1217, 2012.

OLIVEIRA FILHO, A. T.. Floodplain murundus of Central Brazil: evidence for the termite-origin hypothesis. **Journal of Tropical Ecology**, v.8, n.1, p.1-19, 1992.

PALMER, M. W.. Species–area curves and the geometry of nature. In: STORCH, D.; MARQUET, P. L.; BROWN, J. H.. **Scaling biodiversity**. 2007. p.15-31.

PRANCE, G. T.; SCHALLER, G. B.. Preliminary study of some vegetation types of the Pantanal, Mato Grosso, Brazil. **Brittonia**, v.34, p.228-251, 1982.

ROCCHINI, D.. Seeing the unseen by remote sensing: satellite imagery applied to species distribution modeling. **Journal of Vegetation Science,** v.24, p.209-210, 2013.

ROUSE, J. W.; HAAS, R. H.; SCHELL, J. A.; DEERING, D. W.. Monitoring vegetation systems in the Great Plains with ERTS. In: ERTS SYMPOSIUM, 3. **Anais.** NASA SP-351 I, 1973. p.309-317.

SILVA, M. P.; MAURO, R. A..; MOURÃO, G.; COUTINHO, M.. Distribution and quantification of vegetation classes by aerial survey in the Brazilian Pantanal. **Rev. Bras. Bot.,** v.23, n.2, p.143-152, 2000.

SOARES, J.; DANELICHEN, V. H. M.; PEREIRA, O. A.; MARTINS, A. L.. Estudo da dinâmica espaço-temporal do NDVI no Município de Sorriso/MT. **Revista Brasileira De Geografia Física,** v.13, p.834, 2020.

SOUZA, C. A.; DANELICHEN, V. H. M.; BIUDES, M. S.; SILVEIRA, S. W. G.. Change in Biophysical Parameters from the Creation of a Natural Monument in Mato Grosso. **Revista Brasileira de Geografia Física,** v.11, p.2427-2435, 2018.

VALERIANO, M. M.; ABDON, M. M.. Aplicação de dados SRTM a estudos do Pantanal. **Revista Brasileira de Cartografia,** v.59, n.1, p.63-71, 2007.

WATSON, D. J.. The physiological basis of variation in yield. **Advances in Agronomy**, San Diego, v.4, p.101-144, 1952.

WILKS, D. S.. **Statistical methods in the atmospheric sciences.** Academic Press, 2011.

ZHENG, G.; MOSKAL, L. M.. Retrieving leaf area index (LAI) using remote sensing: Theories, methods and sensors. **Sensors**, v.9, p.2719-2745, 2009.