ISSN:1984-2295

Revista Brasileira de Geografia Física

Homepage: www.ufpe.br/rbgfe

Change in Biophysical Parameters from the Creation of a Natural Monument in Mato Grosso

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Artigo recebido em 09/11/2014 e aceito em 24/02/2015

A B S T R A C T

Among the categories of conservation units, the Natural Monument (MoNa) presents a high challenge because it is established areas. MoNa Morro de Santo Antônio is the only one in the state of Mato Grosso and degree of preservation is unknown. Thus, the objective of this work was to evaluate the use and occupation of the soil after the creation of MoNa Morro de Santo Antônio in the state of Mato Grosso and its influence on biophysical parameters from remote sensing techniques. For this, images of the surface reflectance obtained by Landsat 5 and 8 were used. The vegetation classification in the MoNa Morro de Santo Antônio was supervised. The estimated biophysical parameters were the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and the Normalized Difference Moisture Index (NDMI). The results presented in this work show that after the creation of MoNa Morro de Santo Antônio the native Cerrado class increased by 3.38%, the Undergrowth vegetation increased by 5.59% and the Forest dense class increased from 2.21% between 2006 and 2015. The Undergrowth vegetation class had a greater predominance. All indexes were lower in 2006 and higher in 2015. The results of this study are preliminary, but indicate that the creation of MoNa Morro de Santo Antônio in Mato Grosso influenced the preservation of its vegetation.

Key words: Conservation Units, vegetation index, orbital sensors.

Introduction

The conservation units are implanted with different levels of restriction, among them the direct or indirect use of the natural resources, possessing different conservation attributes for each category of management to be preserved (Santos, 2006; Lopes e Vialôgo, 2013).

The MoNa Estadual Morro de Santo Antônio is considered the only Historic Monument recognized by the State of Mato Grosso. This MoNa is part of the official Coat of Arms of the state of Mato Grosso because it was a point of support in the Paraguayan War. MoNa Morro de Santo Antônio covers an area of 258.09 ha and was established in 2006 with the basic objective of preserving rare, natural or scenic beauty sites (MATO GROSSO, 2006). The area of MoNa Morro de Santo Antônio, before its creation, had several uses and is frequently hit by fires. However, the degree of preservation of the MoNa Morro de Santo Antônio after its creation is unknown.

In this context, the use of remote sensing can contribute to know if there was preservation of the MoNa Morro de Santo Antônio area after its creation. There are several biophysical parameters estimated from images of orbital sensors that are often used to monitor and quantify vegetation (Rouse, 1973; Gao, 1996; Huete, 2002).

Thus, the objective of this work was to evaluate the use and occupation of the soil after the creation of MoNa Morro de Santo Antônio in the state of Mato Grosso and its influence on biophysical parameters from remote sensing techniques.

Material and methods

The research was carried out in a conservation unit, denominated Morro de Santo Antônio Natural Monument, created by State Law No. 8,504/2006, with 258.09 hectares, located on the border of the Cuiabá and Santo Antônio de Leverger municipalities, between the coordinates 15° 46'2.604 "S and 56° 5'47.016" W.

The local vegetation is typically of Cerrado de Campo Sujo, presenting deciduous forest in the slope of the hills (Machado, 2008). The soil is

Plintossolo with the presence Litólicos (EMBRAPA, 2006; IBGE, 2007). The local climate is Aw tropical semi-humid, according to the Köppen climatic classification, with two well defined seasons: rainy and dry.

Orbital Sensor Data

The surface reflectance images used in this study were obtained by the Landsat 5 and 8 satellites in orbit 226 and point 071, from 2005 to 2015. These images were obtained on the ESPA platform of the American Geological Survey (http://espa.cr.usgs.gov). Between 2005 and 2011, Landsat 5's Thematic Mapper (TM) sensor surface reflectance images were used, and between 2013 and 2015, Landsat 8's Operational Land Imager (OLI) sensor. Each image was obtained at spatial resolution of 30 me with atmospheric correction made by the USGS (Masek, 2006).

Surface Cover classification

A supervised classification was performed with NDVI charts (Rouse, 1973). The three classes were established: Cerrado, Undergrowth vegetation and Forest dense, according to Cordeiro (2002). The biophysical parameters were estimated using the vegetation and humidity indices (shown below), calculated from the reflections of the Landsat 5 and 8 satellites. The red and near infrared bands are represented by ρ_3 and ρ_4, respectively, which correspond to to bands 3 and 4 of Landsat 5 satellite, and to bands 4 and 5 of Landsat 8 satellite.

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) was obtained according to equation (1), using the near infrared and red band reflectance's. Its value ranges from -1 to +1 (Rouse, 1973).

$$NDVI = \frac{(\rho_4 - \rho_3)}{(\rho_4 + \rho_3)} \tag{1}$$

Enhanced Vegetation index (EVI)

The Enhanced Vegetation Index (EVI) was calculated according to Equation (2), using the bands of red, near infrared, and blue (Huete, 2002).

$$EVI \quad \frac{(\rho_4 - \rho_3)}{(\rho_4 + 6\,\rho_3 - 7.5\,\rho_1 + K)} \tag{2}$$

Normalized Difference Moisture Index (NDMI)

The Normalized Difference Moisture Index (NDMI) was calculated according to Equation (3), using the near infrared and green bands (Gao, 1996).

$$NDMI = \frac{(\rho_4 - \rho_5)}{(\rho_4 + \rho_5)} \tag{3}$$

Results and Discussions

Soil Use and Land Use Change Assessments

In 2005, the native Cerrado class accounted for 70.7% of the study area. In 2015, this class represented 68.8% (Table 1).

According to Budke et al. (2009), these decreases in biomass are related to the change in adverse physical characteristics. Li et al. (2018) point out that species richness determines the biomass biodiversity above the soil, these vegetation strata, which determine the variations in the indices, for each phytophysiognomic type.

After the creation of MoNa in 2006, the native Cerrado class increased by 1.46 percentage points, compared to 2005. Comparing the year 2006 with respect to 2015, there was an increase of 3.38%. In 2008, the Cerrado Native class represented the largest occupied area with 91.22%, thus demonstrating an increase in occupancy of the area of 20.54%, in relation to the decade studied.

Comparing the year 2007 with the year 2008, there was an increase of 8.68%. And when comparing the year 2006 with the year 2007, there was an increase of 10.40%. Danelichen (2015) in his study at RPPN Sesc Pantanal (Poconé/MT) identified the shrub vegetation that corresponds to most of the reserve, with its fragmented distribution in the landscape. Very close relationship found in MoNa, in the native Cerrado phytophysiognomy.

The table 1 shows that in 2009 there was a reduction in the Cerrado Class of 7.53% in relation to 2008, but compared to the year of the child's birth, there was an increase of 11.56%. Machado et al. (2004) indicate that 2.2% of the original Cerrado coverage in the whole country is inserted in protected areas.

Table 1: Vegetation cover classification of the study area.

Image	Classes	Area (ha)	Area (%)
2005	Cerrado	195.66	70.68
	Undergrowth Vegetation	10.17	3.67

	Forest dense	71.01	25.65
2006	Cerrado	199.71	72.14
	Undergrowth Vegetation	28.71	10.37
	Forest dense	48.42	17.49
2007	Cerrado	228.51	82.54
	Undergrowth Vegetation	16.20	5.85
	Forest dense	32.13	11.61
2008	Cerrado	252.54	91.22
	Undergrowth Vegetation	14.94	5.40
	Forest dense	9.36	3.38
2009	Cerrado	231.00	83.70
	Undergrowth Vegetation	22.00	7.97
	Forest dense	23.00	8.33
2010	Cerrado	201.78	72.89
	Undergrowth Vegetation	48.42	17.49
	Forest dense	26.64	9.62
2011	Cerrado	209.61	75.72
	Undergrowth Vegetation	49.77	17.98
	Forest dense	17.46	6.31
2013	Cerrado	202.00	72.92
	Undergrowth Vegetation	43.00	15.52
	Forest dense	32.00	11.55
2014	Cerrado	180.00	65.02
	Undergrowth Vegetation	38.43	13.88
	Forest dense	58.41	21.10
2015	Cerrado	190.35	68.76
	Undergrowth Vegetation	44.19	15.96
	Forest dense	42.30	15.28

It is observed that the Morro de Santo Antônio presented a reduction in the Class of the Cerrado from 2010 to 2009 of 10.81%. Pinheiro (2009) studying the dynamics of the natural vegetation physiognomies of the Cerrado in the Ecological Station of Assis (SP), for 44 years, observed the gradual evolution of the open formations (Campo, Campo Cerrado and Cerrado typical) to other more closed (Cerrado denso and Cerradão).

The interpretation of the images shows that after the year 2009 the class of Cerrado Native presented a decrease of the occupation of Cerrado area in relation to the years between 2011 to 2014, with a reduction of 12.48%. Compared to the year of the child's birth, there was a reduction of 0.92%, between 2011 and 2014, characterized by Pinheiro (2009), who emphasizes that the reason is related to the decrease in coverage of the Cerrado Class is through deforestation occurred in a rural property within the limit of the Conservation Unit, this process of disturbances delays the gradual evolution in the vegetation.

Costa et al. (2017) report that the existence of a conservation unit (Proteção Ambiental Triunfo do Xingu), has a great challenge with the use of natural resources and threats to natural resources, they point out as difficulties to control land use and occupation.

According to Sousa et al. (2016) verified that approximately 60% of the lands are legally protected areas, including Conservation Units and Indigenous Lands, in a study in the municipality of São Félix do Xingu (Pará), observed a chronic situation of conflicts and violence found in areas private settlements, rural settlements, public areas and vacant lands. The result is the expansion of deforestation and the devaluation of the land, data are also observed by Doblas (2015) in the Iriri River region.

Table 1 shows the occurrence of the occupation area of 12.29% of Undergrowth vegetation during the decade studied. In 2005, Undergrowth vegetation represented 3.67%, and after a long interval of ten years, in 2015, there was a greater occupation of 15.96% around the conservation unit. Pereira et al. (2009) found that the areas of low reflectance are linked to the soil cover type in the Serra do Tabuleiro State Park (Santa Catarina). Sothe et al. (2017) verified that the absorption of chlorophyll by vegetation is detected by the near infrared, identifying soil with high reflectance due to the presence of vegetation.

After the creation of the Monument in 2006, there is a 6.70% increase in the Undergrowth Vegetation class, compared to 2005. Comparing the year of creation with the year 2015, there is a 5.59% increase in vegetation primary, characterized as maximum expression in fragmented area. Piazza et al. (2016) found that the Atlantic Forest biome should also be more rigorous to deforestation, but environmental legislation permits clearcutting, as well as other biomes (CONAMA, 1994; Sano et al., 2008).

Between 2007 and 2009, there was a reduction of the occupied area of 3.96% around the Undergrowth vegetation class compared to the year of creation of MoNa. It is observed that the years 2007 to 2009 represent an average of 6.41% of the area occupied in the Conservation Unit. In 2010 and 2011 there was an increase of 7.36% in relation to the year of creation of MoNa, in 2011 it was 17.98%, mentioning the greater dimension of occupation of the Undergrowth vegetation resulting from the restoration of natural ecosystems, by the process of ecological succession (CONAMA, 1994; Carvalho et al., 2017).

According to Arekhi et al. (2017) working with diversity investigations, reported that the uses of high resolution remote sensing data may characterize the dense vegetation of the Undergrowth Vegetation. In 2013 and 2014, there is still a growth in the area occupied by Undergrowth Vegetation at 4.33%, compared to the year 2006. Eiten (1983) classified the Underground Vegetation that occurs between the rocks in the part of the hilltop, as Campos de Altitude. It is also observed that the class of Underground Vegetation in the year of 2013 registered 15.52%, a higher value that was recorded in the year 2014 with 13.88%, and greater than 2015, of 15.28%. According to Mayer et al. (2017) concluded that the Undergrowth Vegetation, react individually depending on the species and the elevation and trampling. According to Zhou et al. (2018) reported in their results of China's ecological restoration programs, reported that pastures suffer a significant increase in biomass in the area since 2000, which was attributed to the reduction of trampling pressure decrease in density of impact. Joining the years 2013 to 2015 represents 125.62 hectares, which shows an increase of the occupied area of 13.16 hectares by the Undergrowth Vegetation inside the Natural Monument Morro de Santo Antônio compared to the year of creation of the Monument (Table 1).

Analyzing the classification of the Forest dense class between 2005 and 2015, there was a reduction in its area of occupation of 10.37%. Table 1 shows that in 2005 the forest dense represented 25.65%, while in the year 2015 it fell to 15.28%. This class is the denser and higher physiognomic type among the physiognomies grouped in the Cerrado, being found in the dense Cerrado in small transition areas from the typical Cerrado to the Cerradão (Durigan et al., 2004). According to Li et al. (2018) found that the effects of response variables are linked to high trees, with better environmental conditions, above ground, receiving, but solar radiation and short trees, does not present this richness in their biomass.

After the creation of MoNa (2006), there was a reduction of 8.16% in relation to 2005, compared to 2015, there was an increase of 2.21% in the occupation of Forest dense. Cardoso (2009), in his study at RPPN Ecological Station of Panga (Uberlândia, MG), shows that the distribution of Forest dense has the largest surface presence of very little slope, very close to that found in MoNa.

In the years 2007 to 2013, there was a reduction of 9.02% in the occupied area of Forest dense in relation to the year of creation of MoNa, observing that the sum of the years from 2007 to 2013 represents 23.16 hectares of the occupied area in the Conservation Unit (Table 1). Júnior et al. (2008) studying the Chapada dos Veadeiros National Park (State of Goiás) observed that in the Forest dense class, it has higher spectra in the rainy season.

According to the analyzed interpretation of Forest dense, we have seen that it is concentrated in the year 2014. It has an occupied area of 21.10% of MoNa, with predominance of arboreal species and the highest canopy formation, presented the biomass richness (Ribeiro, 1998; Li et al., 2018). This size of the area found in 2014 is greater than the year 2006, with an increase of 3.61%, a figure that surpassed until the year 2015, which is represented by 15.28% of the area of the conservation unit, when comparing the year 2014 to the year 2015, occurring a decrease of the Dense Forest of 5.82%.

Analysis of Vegetation Indices

There is an increase in the NDVI median of 0.20 when compared to 2005. Comparing the year 2006 with the year 2015, the median increases to 0.69 (Figure 1). The maximum NDVI in the vegetation generally occurs in June, two months after the rainy season (Gurgel et al., 2003; Adami et al., 2008). Júnior et al. (2008), characterize the behavior of NDVI with higher values in the rainy season.

The results obtained from the median were 0.50 in 2007, and 0.39 in 2008, thus considering the lowest index of all years analyzed. Skakun et al. (2018) show that the NDVI/MODIS data can be applied with an index lower than 0.02-0.05, depending on the spatial scale. Gurgel et al. (2003) observed that in the month of September, at the end of the dry period, the response of the variation of the driest climate measure, there is a probable degradation. Mao et al. (2018) observed that this change in the climate leads to losses in the area, the values are minimal and well defined, the variability of the NDVI in the Cerrado is due to the fall of the leaves, causing the decreases of the area reflected by the vegetation (Liesenberg et al., 2007). This decline in vegetation index may be related to the direct impacts reached, mainly by the burn, given by Gillespie et al. (2018) in the National Recreation

Area of the Santa Monica Mountains.

The NDVI in the year 2009 presented an increase, reaching 0.56, an oscillation in relation to the median analyzed in 2008, with an increase of 0.15. Liesenberg et al. (2007) and Gillespie et al. (2018) show that the NDVI and EVI profile is consistent with the seasonal dynamics of the vegetation. Madonsela et al. (2018) working with the NDVI in the savanna forest of Southern Africa found 0.49 during the senescence period. The high value of NDVI can also be explained by the large number of semi-deciduous species (Hermuche, 2011). Lamchin et al. (2018) indicated that there is a relation of the decay of the vegetation and the lack of rain. Filippa et al. (2018) demonstrate that NDVI detects structural changes in the canopy, which cannot be detected by visible wavelength images.

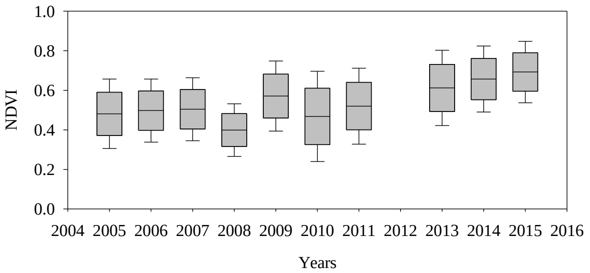

Figure 1: Boxplots of Normalized Difference Vegetation Index - NDVI, in MoNa.

From 2010 the median was 0.46, presenting a decrease in the index to median of 0.10, in relation to the year of 2009, thus occurring a decrease in reflectance of the NDVI, which is sensitive to phenological variations of the canopy of the Cerrado. Ferreira et al. (2006) observed that in the Brazilian Cerrado as it moves toward the more arborescent phytophysiognomies, there is an increasing trend of differentiation between the temporal response patterns of vegetation indexes (EVI and NDVI).

Mo et al. (2018) show that in the coastal region of Louisiana, the NDVI and EVI to be more sensitive, provided solutions to evaluate the biomass of the coastal marshes, and detected the impacts on the composition of species of the diverse ecosystems. NDVI was sensitive to phenological variations in the vegetation, being evident in the year of 2011, with an increase in the median of 0.51 (Figure 1). Resende et al. (2015), found in the National Park of the Chapada das Mesas (states of Maranhão and Tocantins), these same variations in the NDVI.

In the year 2013 the median was 0.60, and 0.65 in 2014, with an increase in reflectance. Resende et al. (2015) report that the indices may suffer several factors, this oscillation depends on the interference in the canopies of the vegetation in the growing period.

The analysis shows that in 2005, before the creation of MoNa, the median EVI was 0.47, and that over a decade, and therefore in 2015, there was an increase. The MoNa area is characterized with great biological diversity and minimal anthropological effects (CONAMA, 1994; Sano et al., 2008).

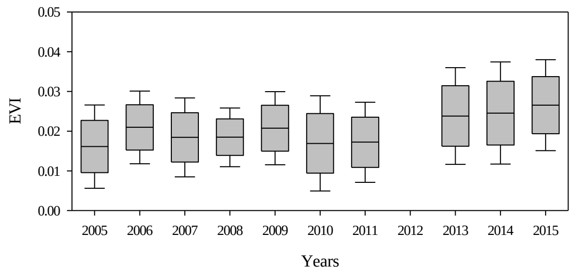

Figure 2: Boxplots of Enhanced Vegetation Index (EVI), in MoNa.

The EVI in the year 2006 registered a median of 0.021, with an increase in the year 2015 with a median of 0.026, with a difference of 0.005 in relation to the year of creation (Figure 2). This index allows a better monitoring of vegetation through the reduction of canopy substrate and the influence of the atmosphere (Huete et al., 1997). According to Nay et al. (2017) recorded in EVI in tropical Sri Lanka in California, values between 0.5 and 0.8 indicating healthy vegetation, and low EVI values are suggestive of stressed vegetation or atmospheric noise.

In the years 2007 and 2008 the median was 0.018, thus a decrease in the EVI, when compared to the year 2006, has a difference of 0.003, with a decrease in the index (Figure 2). Goltz et al. (2007) state that the Enhanced Vegetation Index (EVI) product is more sensitive to changes in soil cover.

Ferreira et al. (2006) verified the sensitivity of the EVI and NDVI vegetation indices using the MODIS sensor from the Ecological Park Altamiro de Moura Pacheco, Emas National Park, Brasilia National Park and Chapada dos Veadeiros National Park (State of Goiás) that the sensitivity of the vegetation indices EVI and NDVI using the MODIS sensor comes from the seasonal variations. Also given by Ratana et al. (2005) state that the sensitivity of the EVI and NDVI indices in the physiognomy of the Cerrado biome varies according to the seasonal changes. Also confirmed are Bascietto et al. (2017) that analyzing EVI data found in Central Europe are altered according to the phenological variations in the temperature decrease.

In 2009, the EVI presented a median of 0.021, the same value also recorded in 2006, the year of creation of MoNa (Figure 2). In the years 2010 and 2011 the median was 0.017, causing a decrease in the EVI of 0.004 when compared with 2009, observing a decrease in the median. Gillespie et al. (2018) declined in the index in the Channel Islands (France) due to the regional drought impacts.

Ferreira et al. (2005) pointed out in the studies in the Cerrado biome, the EVI index with the best performance for the places where there is a greater occurrence of the herbaceous formations, in the years of 2003 and 2004 the median was of 0.023, registering an increase in the EVI of 0.06 compared to 2010 and 2011 years, demonstrating a characterization in natural processes of ecological succession (CONAMA, 1994; Sano et al., 2008).

In 2005, the EVI presented a median of 0.015, thus observing that during the decade, there was an increase in EVI with an increase of 0.011 when compared to the year 2015, showing that the vegetation of the cerrado can recover, even with the anthropogenic actions before the creation of MoNa Morro de Santo Antônio (Figure 2).

The NDVI found in MoNa presents values of reflectance higher than those exhibited by EVI. Nery et al. (2014) also found this difference between the NDVI and EVI indices in the Lapa Grande State Park (Montes Claros/MG). Results found also by Dalla Nora et al. (2010).

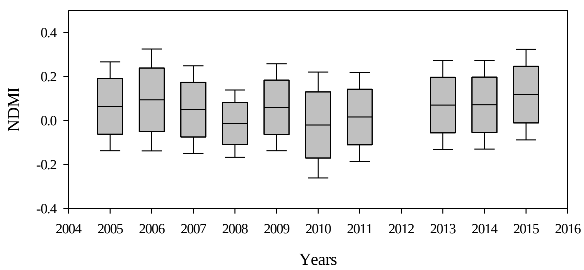

Figure 3: Boxplots of Normalized Difference Moisture Index - (NDMI), in MoNa.

After the creation of the Conservation the NDMI evidenced the growing behavior of leaf water, the median was 0.09, in relation to that which represents the increase of the amount of the tree extract of 0.03, when to be compared to the year of 2015, which was 0.12, it is noted that the moisture at the soil surface strengthens the vegetation development and the foliar expansion of the plants and in the photosynthetic process (Figure 3). Nie et al. (2017) identified, through the NDMI data, great risk vulnerability in the sampled lake.

In 2007 the median was 0.04, a decrease of 0.05 in relation to the year of creation of MoNa. This fall was also observed in the year of 2008, with the lowest value of soil moisture being recorded (Figure 3). Except for NDMI, the performance of all water indices was between 60% and 70%. Therefore, we have shown that both water bodies and saturated soils can be successfully identified (Balázs et al., 2018).

According to precipitation data recorded by the National Institute of Meteorology of Brazil (INMET), at the date of the image scene, there was no precipitation, the reduction in the amount of available water in the soil leads to the leaf fall, reducing the photosynthetic intensity, detecting a structural change in the canopy, thus leading to the fall of NDMI (Kudrev et al., 1994; Filippa et al., 2018).

The NDMI in the year 2009 presented a median of 0.05 increasing soil moisture, in 2010 and 2011 the median was 0.01, observing a decrease in the median of the reflectance of 0.04, when compared to the year of 2009. Junior et al. (2010), in their study in the Serra da Canastra National Park (São Roque/MG) reported that the rock and herbaceous vegetation presented a relation very close to the value of NDMI.

In the years of 2013 and 2014 there was an increase in NDMI (Figure 3). When compared to the years 2010 and 2011, the median increase was 0.06. The sensitivity in the NDMI index found in studies by Yang et al. (2017) served as a basis for forecasting lakes to prevent future changes. Data also found by Mukherjee et al. (2018) used NDMI data, demonstrated floods on the Ganga River and Kalindri (eastern India) in the years 1998-1999.

The NDMI in 2005 was the median of 0.05, after a decade there was an increase of 0.07 when compared to the year 2015, verifying that the soil can store a volume of moisture in the vegetation (Gao, 1996). According to Townsend (2010), this condition favors ecological sequences of the environment.

Conclusion

After the creation of the MoNa Morro de Santo Antônio, the Cerrado native class increased by 3.38%, the class of underbrush vegetation increased by 5.59%, and the Mata class increased by 2.21%. In the year 2015, there was predominance of undergrowth.

The results presented through vegetation indexes in the unit showed a growth in vegetation during the analyzed period. The vegetation indexes registered in the year of the creation of MoNa Morro de Santo Antônio in 2006 were lower than those recorded in 2015. This indicates that there was growth in the vegetation, being confirmed by NDVI, EVI and NDMI recorded in the last year, which exceeded the year of creation.

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